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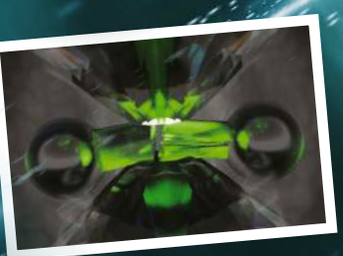
CHASING THE GHOST PARTICLE

A century-old mystery solved at the South Pole

"We knew the universe would never be the same again"



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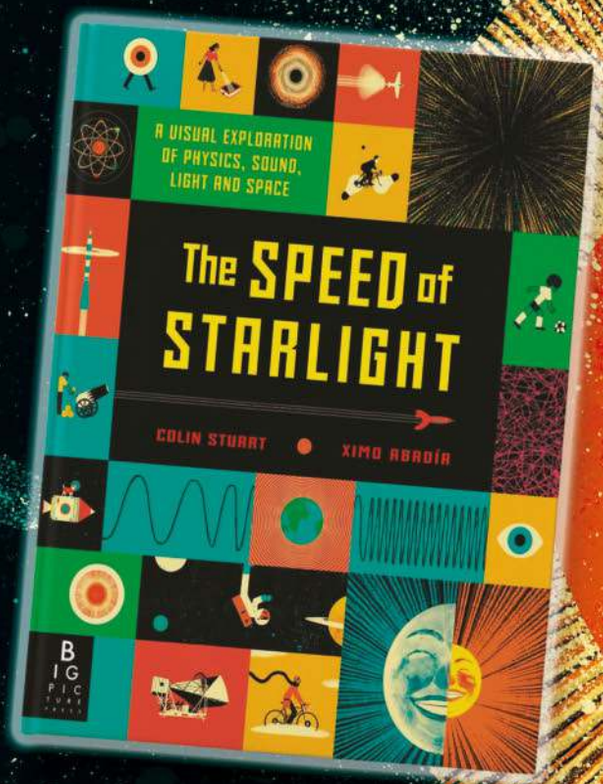

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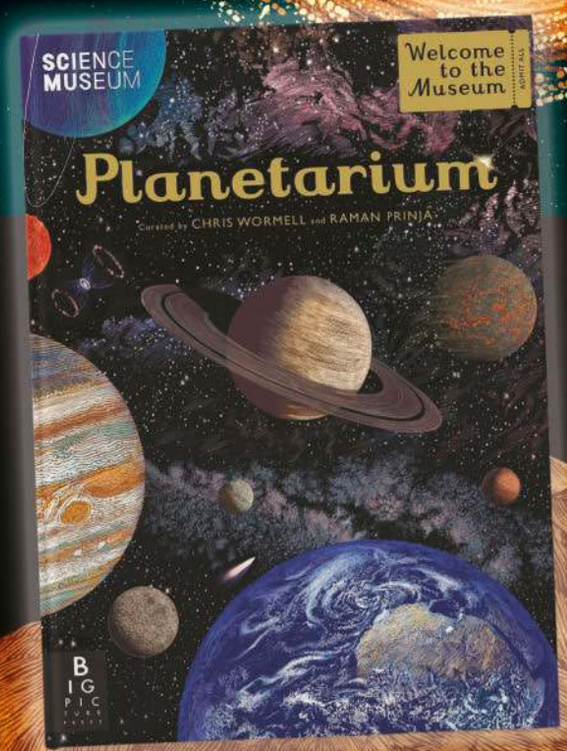

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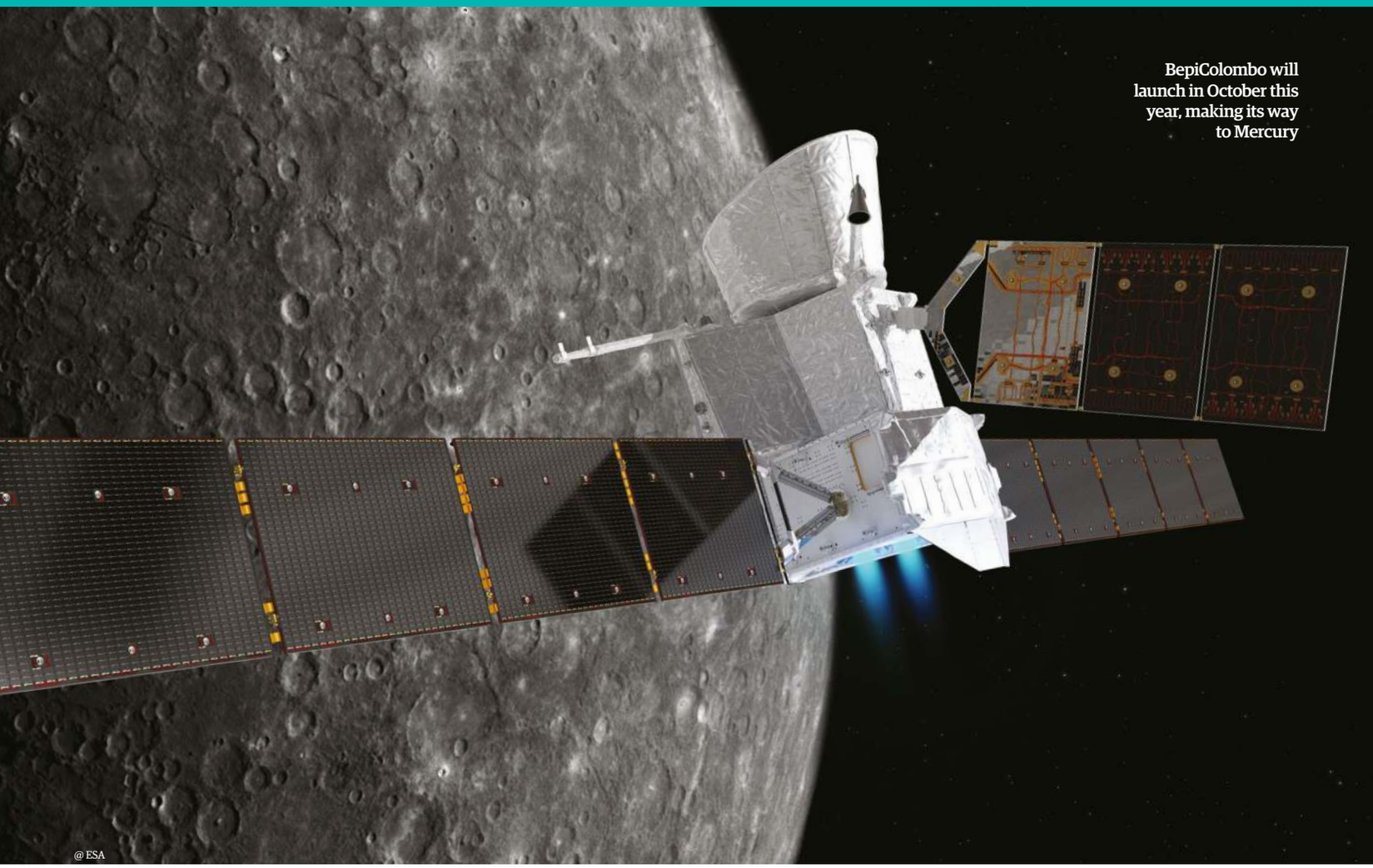

BepiColombo will launch in October this year, making its way to Mercury

Welcome

You've probably heard much about a so-called ghost particle in the news recently; a member of the fundamental family of particles that make up all known matter and move unimpeded through the universe, interacting with almost nothing, you can see how they get their name. But astronomers know them as something that's much more familiar to you and I - the neutrino. You'd be right in thinking that they are made in the Sun, but they also hail from a more-distant location: a super-active galaxy that's firing high-energy ghost particles right at us.

What's particularly interesting about these cosmic neutrinos is that, as you'll discover on page 16, we've finally pinpointed where they're coming from in deep space. What's more, now that we've finally caught these speed freaks we're able to work out much more about their role in the universe. Take a trip over to the bottom of the world - that is, the Antarctic - with us to find out more.

Elsewhere in the issue we uncover whether there is a hole in the Sun, and meet the scientists who actually make planets in a laboratory here on Earth. What's more, we've also got plenty for you to get stuck into in terms of stargazing.

Make sure you download your free astroimaging pack with this issue, and don't forget to claim your free brass telescope when you subscribe to the magazine.

Gemma Lavender
Editor

Our contributors include...

Ben Gilliland
Award-winning book author
We're chasing down the ghost particle this month – Ben finds out what a recent discovery means for our understanding of space.

Kulvinder Singh Chadha
Space science writer
Kulvinder gets to the bottom of whether there's a hole in the Sun and reveals how we don't really know our nearest star at all.

Lee Cavendish
Staff Writer & astronomer
Mission to Mercury BepiColombo is getting ready for launch. Lee speaks to its scientists about what they hope it'll uncover at the planet.

Ian Evenden
Space science writer
This month officially marks the 60th anniversary of NASA. Ian highlights its greatest achievements and speaks to the agency's scientists for their vote.

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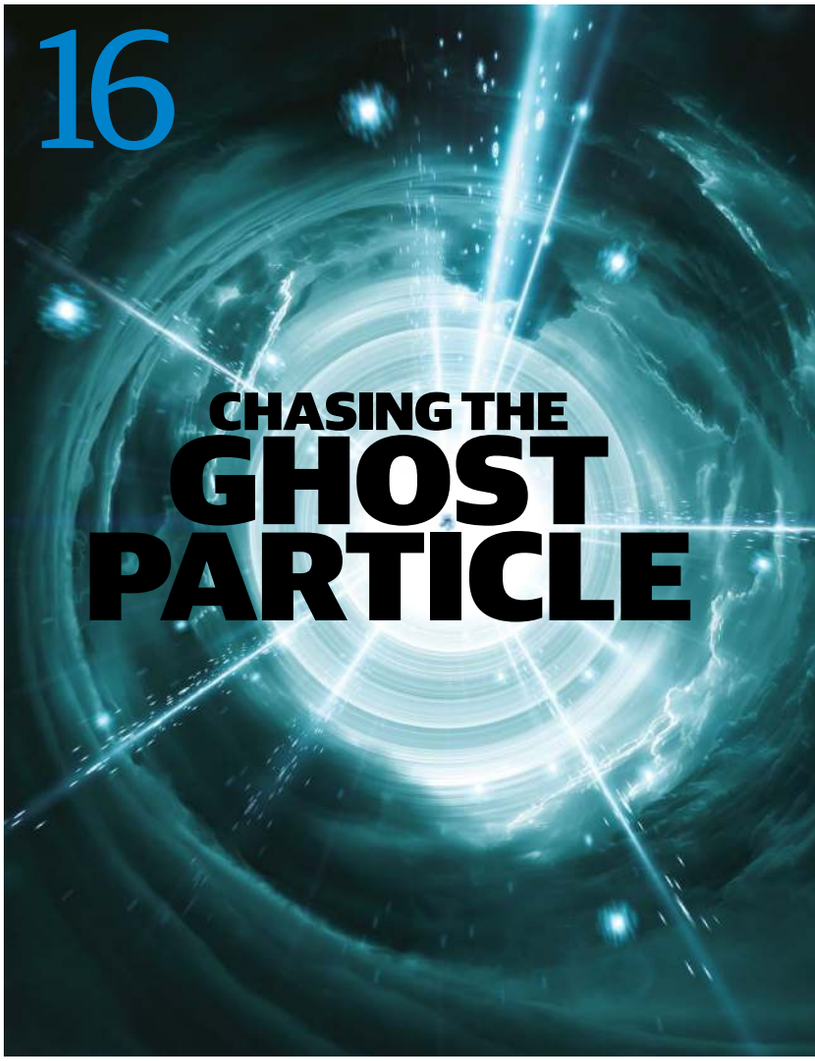

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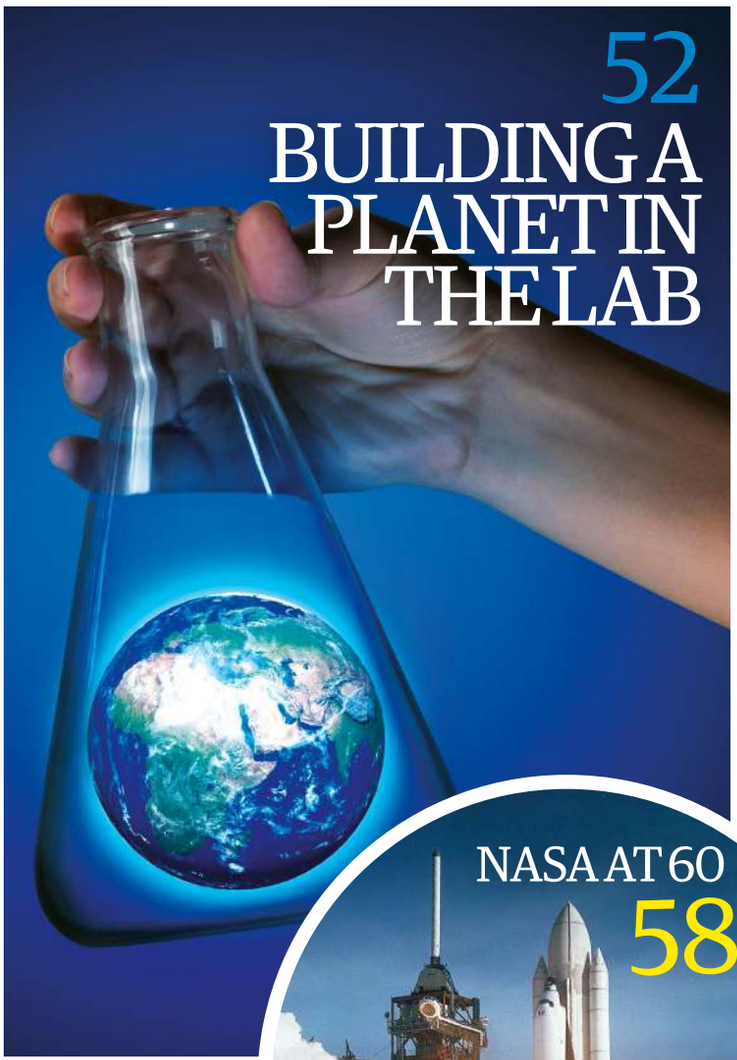

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The first probe to touch the Sun

NASA's mission to send the first space probe towards the largest, hottest and most volatile object in our Solar System was finally launched on 12 August 2018. On the tip of a United Launch Alliance Delta IV Heavy rocket, Parker Solar Probe is finally on its way to make history in space exploration.

The Sun's erratic and unusual behaviour has been the subject of many studies, however, this mission will supply the first set of concrete data about the object itself. This information will add valuable constraints to many theories to help scientists gain a better understanding of our nearest star.

A dusty world at its best

On 27 July 2018, astronomers were treated to a rare pair of celestial sights. At the same time as a lunar eclipse presented a rare, red 'blood Moon', photographed at ESA's European Space Astronomy Centre in Madrid, Spain, our neighbour planet Mars was at opposition.

When a planet is at opposition, Earth passes between the world and the Sun - in this case, this was our closest view of Mars since 2003, making it ideal for observation. NASA/ESA's Hubble Space Telescope imaged the Red Planet just 13 days before its opposition, revealing the dust storm that had enveloped its entire globe.

Peculiar Portugal

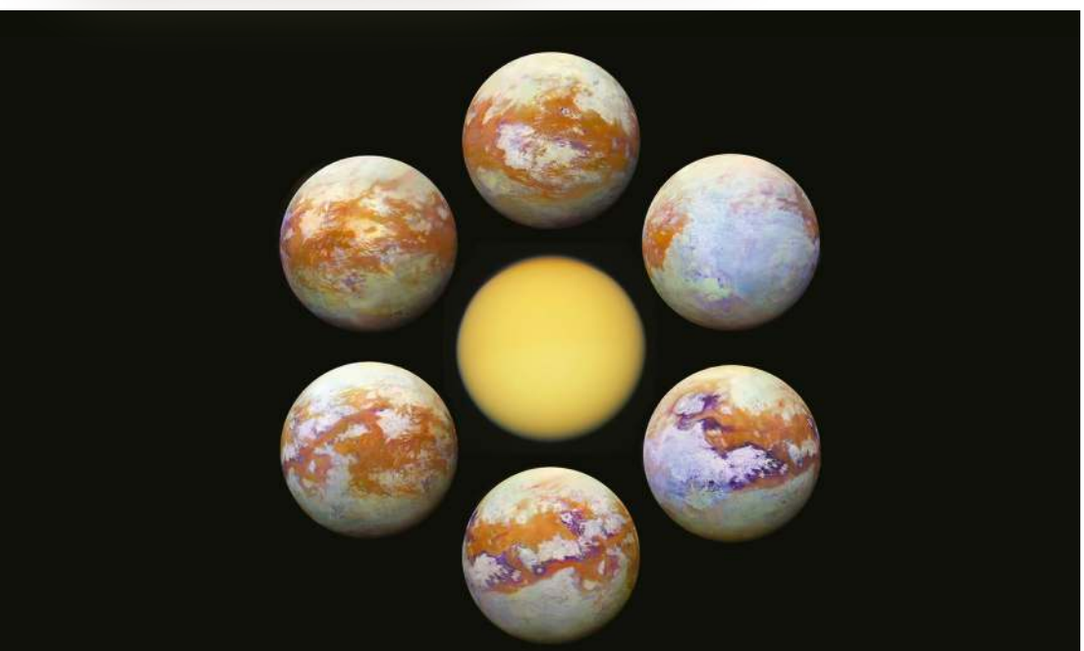
While on board the International Space Station, any large-scale weather changes are extremely noticeable to the astronauts floating 400 kilometres (250 miles) above the Earth's surface. On one of its recent orbits the view of Portugal from space was abnormal.

ESA astronaut Alexander Gerst imaged the Iberian Peninsula and the northern part of Africa. He then uploaded a tweet of the picture with the following caption: "Dramatic weather pattern over Portugal today. Looks like a mixture of dust, sand and smoke."

Big telescope birth

The Extremely Large Telescope (ELT) will be the finest ground-based telescope ever constructed when it is finished in 2024. The European Southern Observatory's (ESO) future 39-metre (128-foot) multi-wavelength telescope is currently in the early stages of its construction on top of the mountain Cerro Armazones in Chile.

This top-down view of the ELT construction site and the surrounding environment looks very bare and extremely dry. These are the ideal conditions for observing the night sky, and along with the high altitude will give crystal clear views.



Infrared eye on Titan

NASA's Cassini spacecraft is still springing surprises about the Saturnian system, in particular the system's largest moon, Titan. Cassini's Visual and Infrared Mapping Spectrometer (VIMS) instrument gathered 13 years' worth of infrared data of the 'Earth-like' satellite from which these infrared maps were formed.

Looking at Titan in the visible light wavelength doesn't reveal much, as the surface of the moon is blocked by an orange, hazy atmosphere. The infrared observations provide a window to the surface, revealing its complex geology.

Sparkling southern sky

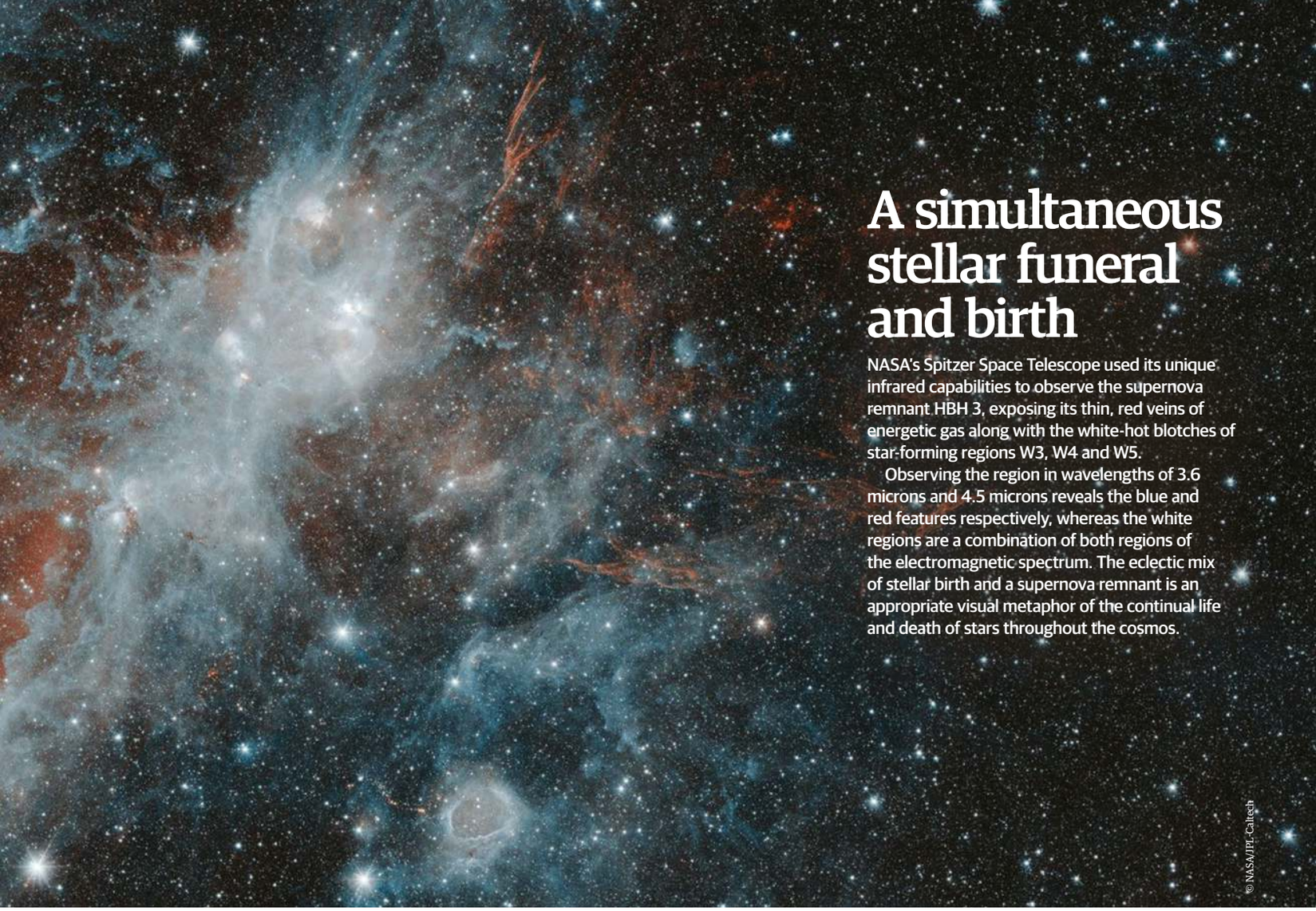
Another telescope searching the skies above Chile is another of ESO's telescopes, a Danish 1.54-metre (5-foot) telescope that makes up one of the telescopes at the La Silla Observatory.

Behind the telescope are some of the amazing stars and nebulae that don't cross the threshold into the Northern Hemisphere. To the left of the dome is the Southern Cross, also known as the constellation Crux, which is the southern equivalent of Polaris (the north star). Above the Southern Cross is the Coalsack Nebula, which is one of the most noticeable dark nebulae that can be seen with the unaided eye.

Peeping inside Orion

NASA's Orion spacecraft is slowly increasing in popularity as the idea for deep-space travel becomes more of a reality. The Orion spacecraft will take future astronauts back to the Moon and beyond to Mars.

The Orion test crew capsule, which will be used for the Ascent Abort-2 (AA-2) test, recently had visitors and was shown around by Orion AA-2 Crew Module manager Dr Jon Olansen (left). Also present were Orion Program manager Mark Kirasich (right), NASA Johnson Space Center director Mark Geyer (second from right) and NASA administrator Jim Bridenstine (second from left).



A simultaneous stellar funeral and birth

NASA's Spitzer Space Telescope used its unique infrared capabilities to observe the supernova remnant HBH 3, exposing its thin, red veins of energetic gas along with the white-hot blotches of star-forming regions W3, W4 and W5.

Observing the region in wavelengths of 3.6 microns and 4.5 microns reveals the blue and red features respectively, whereas the white regions are a combination of both regions of the electromagnetic spectrum. The eclectic mix of stellar birth and a supernova remnant is an appropriate visual metaphor of the continual life and death of stars throughout the cosmos.

Space-eye view of the Columbia Glacier

Using the observations of collective wavelengths from Landsat satellites has shown how the Columbia Glacier has changed since 1985. Water from the dense body of ice flows down the Chugach Mountains into a narrow inlet that leads into Prince William Sound in south-eastern Alaska.

Snow and ice are shown here in bright cyan, vegetation in green, open water in dark blue and exposed rock in brown. Over the last three decades the end of the glacier, also known as a terminus, has seemingly retreated to the north by 20 kilometres (12 miles).

NASA seeks to rescue Opportunity rover

Having lost contact with the rover in June, engineers are waiting for the Martian skies to clear

NASA scientists have identified key signs which should enable them to touch base with the Mars Opportunity rover months after it became lost to radio silence.

Space agency staff lost contact with Opportunity on 10 June this year when a dust storm encircled the Red Planet and blotted out the Martian skies.

It was the first time the rover had become cut off after trundling across the surface of Mars for close to 14 years and, having landed on the Red Planet in 2004, scientists are hopeful that its batteries – which were in good health prior to the storm – have held up well.

With that in mind a bid to recover the rover is in full swing, with NASA monitoring Opportunity daily. First they are waiting for the skies to clear so that the rover can receive enough sunlight to recharge the batteries. They are doing this by keeping an eye on the wide-angle camera on NASA's Mars Reconnaissance Orbiter in the hope that the planet's surface features will soon become visible.

Once the amount of sunlight reaches a tau of less than 2.0, it should be able to power up. On 10 June, however, the tau measurement was at 10.8; the higher this number reads, the less sunlight is available. Assuming it does end up recharging, NASA will then use the Deep Space Network to ping the rover during 'wake up' times before searching for signals in response.

Further to that, engineers will be looking out for the fault mode that Opportunity is likely to have entered on 10 June. This could be a low-power fault which causes the rover to hibernate until there's enough sunlight to recharge it. A bigger problem would be a clock fault, in which case it would be more difficult for it to know when it should communicate, although it can assume the time by detecting sunlight increases. An uploss fault would cause the rover to seek new ways to communicate with ground control since it would indicate the rover's communication equipment has taken a bit of a hit.

Unfortunately, NASA says communication won't be immediate. Engineers will have to understand the state it is in, check itstemperature, reset the clock, have it take photos in case of damage and then work out the best time to attempt a full recovery. Even then, there is a chance that the rover will not act in the same way when it wakes because of such prolonged inactivity. This could cause the battery to hold less juice, making future operations more difficult.

"A bid to recover the rover is in full swing"

An artist's concept image of Opportunity, which landed on Mars in 2004

‘Ultra-hot Jupiter’ has heavy metals in its atmosphere

Observations of an exoplanet that is hotter than many stars uncovers a glowing sky of iron and titanium

Iron and titanium have been found in the atmosphere of a planet outside our Solar System for the first time. The heavy metals were detected around KELT-9b, a gas giant 620 light years from Earth, made possible because it also happens to be the hottest exoplanet discovered so far.

Thanks to an equilibrium temperature of 3,700 degrees Celsius (6,692 degrees Fahrenheit), clouds do not condense in the atmosphere. This means the atoms around KELT-9b are not trapped within other molecules and are allowed to fly on their own in their atomic form, better enabling their detection.

Researcher Kevin Heng, who wrote of his observations of the findings in a blog post, says iron and titanium “have long been an ingredient in the theory of exoplanet formation, but they have never been directly detected”. This discovery is able to shed greater light on how planets are formed and why some objects become stars and others gas giants. While there is no chance of discovering life on KELT-9b, the technique used to observe iron and titanium could prove useful for other studies.

Heng told **All About Space** that the technique – which involved examining light from the exoplanet as it passed directly in front of its star – could also be used to detect biosignatures, signs of life.

“On Earth, we think it's oxygen and a few other obscure molecules,” he says, “but we don't know what biosignatures are in general. If you knew what they were... you could use exactly the same technique to detect these molecules in cooler, smaller planets.”

An artist's impression of KELT-9b as it orbits its host star

© NASA/JPL

Revealed: jaw-dropping microscopic image of speck of asteroid dust

Brought to Earth eight years ago, scientists are getting up close to these grains of extraterrestrial rock

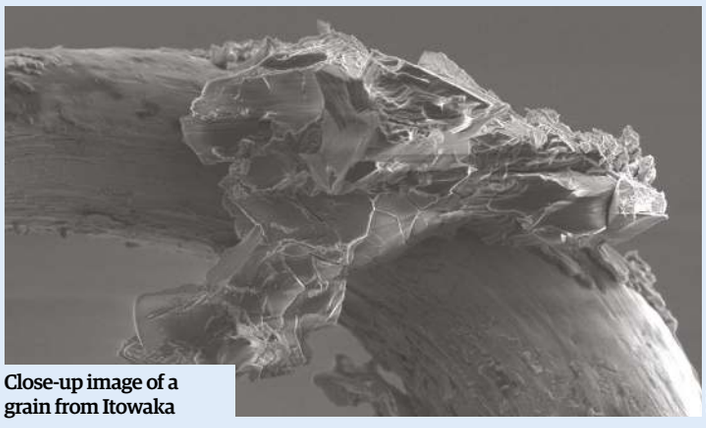
Scientists still studying tiny grains of dust that were collected from an asteroid 13 years ago have released a stunning close-up photograph.

The image shows a single grain of rock, as viewed under a microscope, retrieved from asteroid 25143 Itokawa by the Japan Aerospace Exploration Agency's (JAXA) Hayabusa mission in 2005 along with about 1,500 other samples. It ended up completing a 6 billion kilometre (3.7 billion mile) round trip over seven years.

Tested by researcher Fabrice Cipriani from the European Space Agency, which has three such grains at its ESTEC technical centre in the Netherlands, the hope is that the grain will tell us more about the static charging properties of asteroids.

ESA says this will enable a better understanding of the consequences for the surface environment of asteroids, although other researchers are also studying the grains for more clues about the asteroid's mineralogy and composition. This, Cipriani says, will give more clues about the origin of the Solar System. Not bad for grains that are just 40.95 microns in diameter, which is about the width of an average human hair.

This grain was brought back to Earth from Itokawa in 2010, making the robotic Hayabusa spacecraft the very first to return a sample from an asteroid surface to Earth for study. Cipriani is continuing to look at how static electricity can repel asteroid particles from each other.



Close-up image of a grain from Itowaka

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Hydrogen wall may have formed at our Solar System's border

Data from New Horizons is almost matching that of Voyager, pointing to the potential existence of a visible boundary

NASA scientists are almost certain that their New Horizons probe is able to view the outer boundary of our Solar System. Observations indicate that the probe is seeing extra-ultraviolet light at a point further from the Sun than would otherwise be expected. This is likely to be produced by a wall of hydrogen and would be the point at which our Sun's powerful jets of matter and energy flow have waned, reducing the ability to push back on the bits of dust and other matter which floats within our galaxy's walls.

This is occurring far beyond the orbit of Pluto, which New Horizons flew past in 2015. The probe, which is now 6.4 billion kilometres (4 billion miles) away from Earth, has since been making its way outward towards a mass of interstellar matter, including hydrogen. The measurements being taken by New Horizons are closely matching those made by the Voyager mission 30 years ago. "We assume there's something extra out there, some extra source of brightness," says the paper's author Randy Gladstone.

That said, the ultraviolet light might still be from another source deeper in the galaxy, which is why scientists are awaiting more data.

New Horizons will continue to take 360-degree snapshots of ultraviolet emissions as it prepares to visit the Kuiper Belt Object 2014 MU69 next year. It should mean scientists gain a better idea of the galactic hydrogen wall which is understood to wrap around the Solar System like a bubble and form the threshold between us and the broader galaxy.

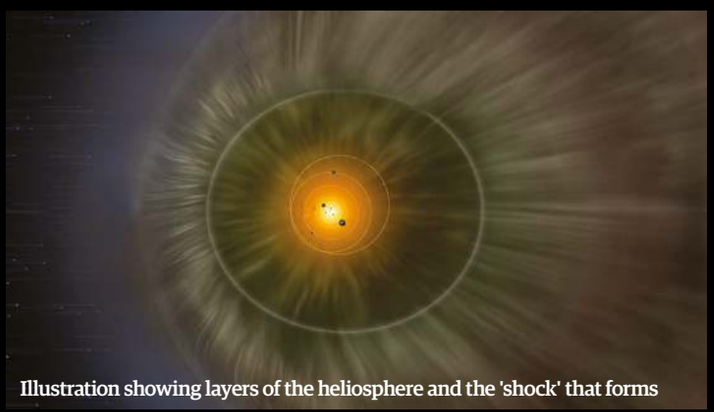


Illustration showing layers of the heliosphere and the 'shock' that forms

NASA's 'Hidden Figures' in line for a top award

US senators seeking to recognise four African-American women for their key roles

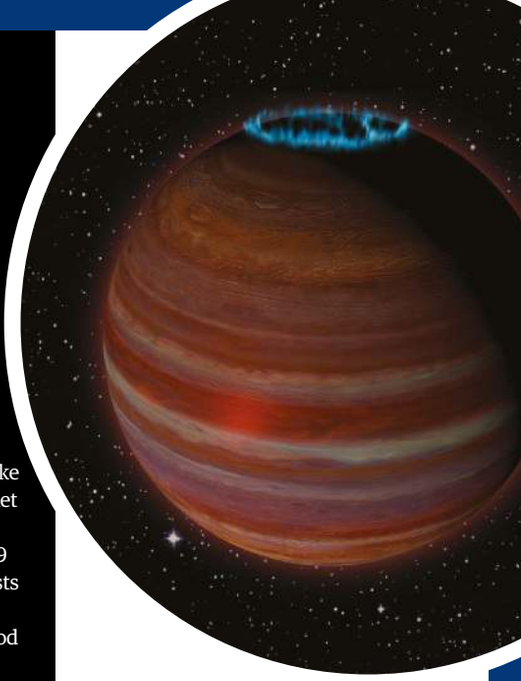
Four brilliant African-American women who played a key role in the Space Race of the 1960s are on course for the USA's highest civilian award. The 'Hidden Figures' – so-called because of a 2016 biographical drama movie which highlighted their roles – could receive Congressional Gold Medals. It would suitably honour the efforts of Katherine Johnson, Dorothy Vaughan, Mary Jackson and Christine Darden more than half-a-century later.

The proposal has been put forward by Senators Chris Coons, Lisa Murkowski, Kamala Harris and 44 colleagues as the 'The Hidden Figures Congressional Gold Medal Act'. "Each of these women played an important role at NASA during the space race, but for many years their accomplishments remained hidden," said Senator Chris Coons in a statement. "This bill will help recognise these extraordinary women and bring their accomplishments into the light so they can serve as an inspiration to younger generations of women in science, particularly those of colour."

Johnson's calculations of orbital mechanics at NASA ensured the success of human spaceflight, including that of the first American in space, Alan Shepard, in 1961, and the first American in orbit, John Glenn, a year later. Her calculations paved the way for the Space Shuttle program, and she was awarded the Presidential Medal of Freedom by President Barack Obama in 2015.

Vaughan became the first African-American supervisor at the National Advisory Committee for Aeronautics (NACA) where she led the West Area Computing unit. Jackson was the first African-American female engineer at NASA while Darden, who spent most of her 40-year career in aerodynamics at NASA, was the first African-American women at the Langley Research Center to be promoted to the top-ranking Senior Executive Service.

Katherine Johnson was one of three black NASA mathematicians highlighted in the 2016 film *Hidden Figures*



Planet-sized object has a powerful magnetic field

The 'world' straddles the boundary between a giant gas planet and a brown dwarf

A 'rogue' planetary-mass object which is 20 light years away from Earth has a surprisingly strong magnetic field, astronomers have discovered. The object – called SIMP J01365663+0933473 – has a magnetic field more than 200-times stronger than Jupiter's but, since it is only 12.7-times more massive than the gas giant, it is still not known whether it is a planet or a star.

Quite how the object is able to maintain such power is now being investigated, with the National Radio Astronomy Observatory saying the study of the magnetic dynamo mechanisms "can potentially help us understand magnetic processes on both stars and planets". It was observed using the Very Large Array, making it the first radio-telescope detection of a planetary-mass object beyond our Solar System. But it also has other unusual properties, not least the fact that it is travelling alone, unaccompanied by a parent star.

"This object is right at the boundary between a planet and a brown dwarf, or 'failed star'," explains Melodie Kao, who led the study while a graduate student at Caltech, and is now a Hubble postdoctoral fellow at Arizona State University. It was originally detected in 2016 and it has a surface temperature of 825 degrees Celsius (1,517 degrees Fahrenheit), compared to the Sun's 5,500 degrees Celsius (9,932 degrees Fahrenheit).

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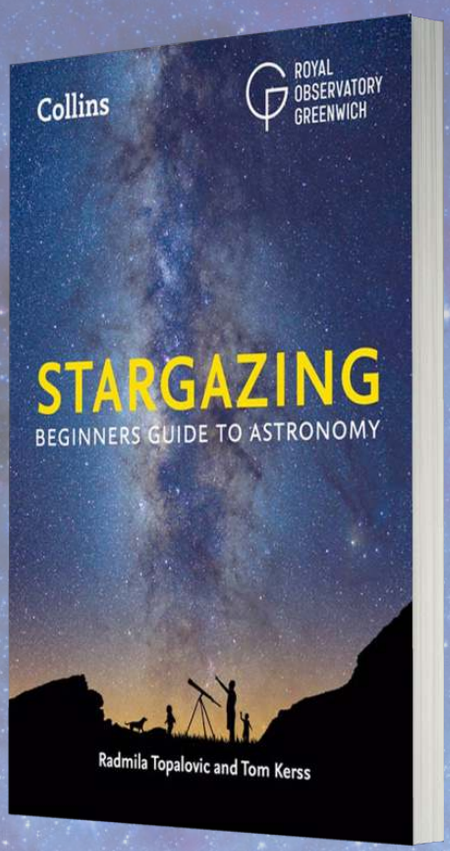
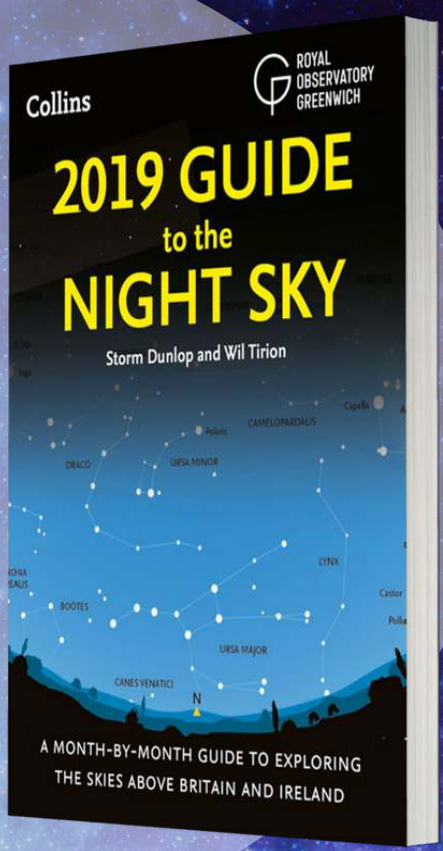
ROYAL OBSERVATORY GREENWICH

Look to the stars with us this autumn





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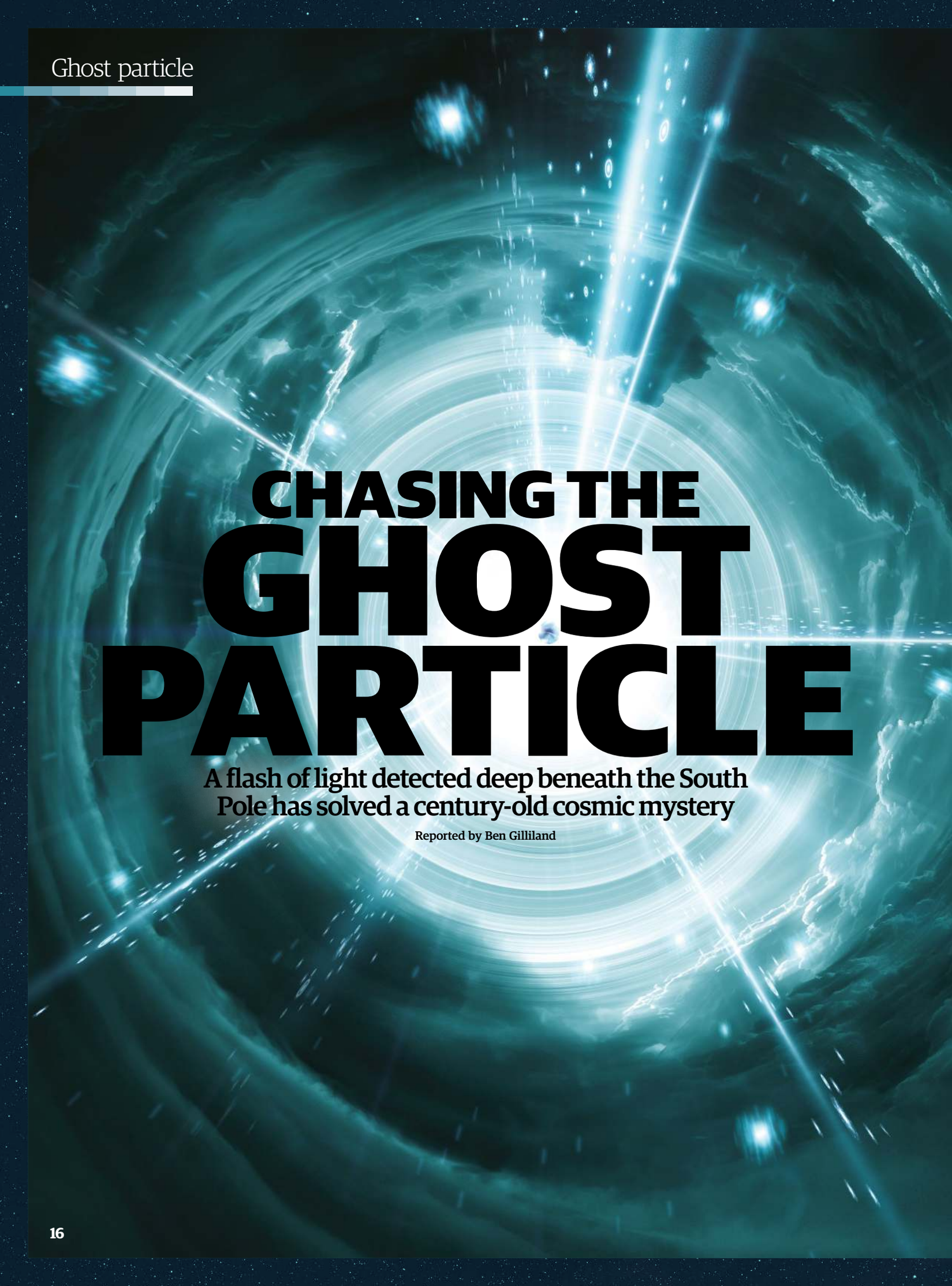


CHASING THE GHOST PARTICLE

A flash of light detected deep beneath the South Pole has solved a century-old cosmic mystery

Reported by Ben Gilliland

For nearly 4 billion years a ghostly traveller hurtled towards our planet at nearly the speed of light – passing through galaxies and skirting alien worlds, but never once deviating from its course.

When its journey began, the distant Earth had been a lifeless lump of rock orbiting a young star. The ghost's journey was so vast that as it travelled, the first single-celled life evolved on Earth, single-celled life became multicellular, complex life blossomed in the seas and conquered the land, the dinosaurs rose and fell and humans took their first tentative steps out of Africa.

Through the entirety of the history of life on Earth, the ghost had journeyed unhindered through the cosmos. Then, on 22 September 2017, it was detected on Earth. And, deep beneath the South Pole it perished. In doing so, it imparted a secret.

This is the story of the hunt for that ghost and the century-old mystery its demise is helping to solve.

Ghost particles are elementary

According to the Standard Model of particle physics, a neutrino is an elementary particle. The elementary particles are building blocks of the universe.

At the turn of the 20th century physicists were busy experimenting with the radioactive element radium (radiation itself had only recently been discovered) when they started to notice something strange – even when the radium was removed their instruments were still registering the presence of energetic particles.

Most scientists of the time believed that the radiation must have been coming from minerals in the ground. But in 1910, German physicist Theodor Wulf, took an electroscope to the Eiffel Tower and tested radiation levels at ground level and at the top of the tower. He found that the effect was actually stronger at altitude – the radiation wasn't coming from the ground.

The mystery was picked up by an Austrian physicist, Victor Hess, who, in a series of daring balloon flights in 1911 and 1912, took radiation readings from ground level to an altitude of 5,300 metres (17,390 feet). He found that although radiation levels initially dropped off, as he gained

A rendering of the track detected by IceCube's sensors on 22 September 2017. It tracks the course of a muon created when the neutrino collided with an atom in the ice. The colours show its direction of travel – from red (first detection) to green and blue

They are born from violence
Neutrinos are created as a by-product of nuclear fusion in stars and in violent astrophysical events like supernovae.

altitude the readings increased until, at the highest altitudes, the radiation levels were many times greater than they were at ground level. Hess concluded that "a radiation of very high penetrating power enters our atmosphere from above". Or, to put it another way, the particles were coming from space. But just how far out in space were they coming from?

One obvious candidate was the Sun, but Hess ruled that out by performing one of his balloon experiments during a total eclipse in 1912 – had particles been coming from the Sun the readings would have dropped off as the Moon covered it up, but the levels remained the same. The only possible explanation was that they came from further out in space. Hess had discovered cosmic rays.

Space is flooded with cosmic radiation in the form of high-energy, charged particles, such as protons and atomic nuclei. These particles can be produced in all sorts of astronomical processes, such as the nuclear reactions in stars.

But then there are the highest energy cosmic rays. These are particles that are imbued with hundreds of millions, or perhaps even billions, of times more energy than those created in human-made particle accelerators. In fact, physicists would need to build a particle accelerator the same size as the orbit of the planet Mercury – about 360 million kilometres (224 million miles) – to reach the energy of the particles in cosmic rays.

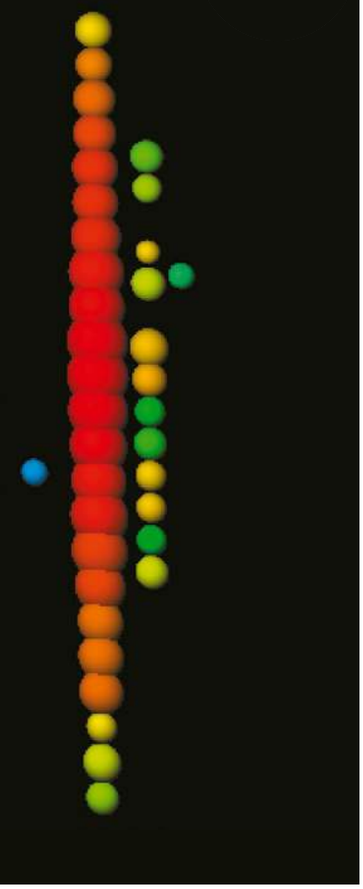
What mechanism could accelerate these particles to the sort of energies that make the Large Hadron Collider look like a particle pea shooter? They must surely come from some of the most violent and least understood objects and events in the universe, such as a massive star dying in a supernova explosion, or from an active black hole in the centre of some distant galaxy. It is a mystery that has endured for more than a century.

Cosmic rays are the fragments of atoms, such as protons, electrons and atomic nuclei, that have been torn apart and accelerated in violent cosmic events. The trouble with these particles is they all carry an electric charge, which means as they fly through space they interact with the magnetic fields of stars and other objects. These magnetic fields attract or deflect the charged particles, which alters their trajectory and makes them swerve around space like a cosmic drunk driver. This means that by the time they reach Earth they can tell us very little about where they came from.

"Space is flooded with cosmic radiation in the form of high-energy, charged particles, such as protons and atomic nuclei"

How they are detected

The discovery of the source required a suite of telescopes – each able to view the universe in a different way – an approach called multi-messenger astronomy



Artist's impression of a blazar shooting a jet of neutrinos and gamma rays that were detected by IceCube as well as other telescopes on Earth and in space

Major Atmospheric Gamma Imaging Cherenkov (MAGIC) Telescopes

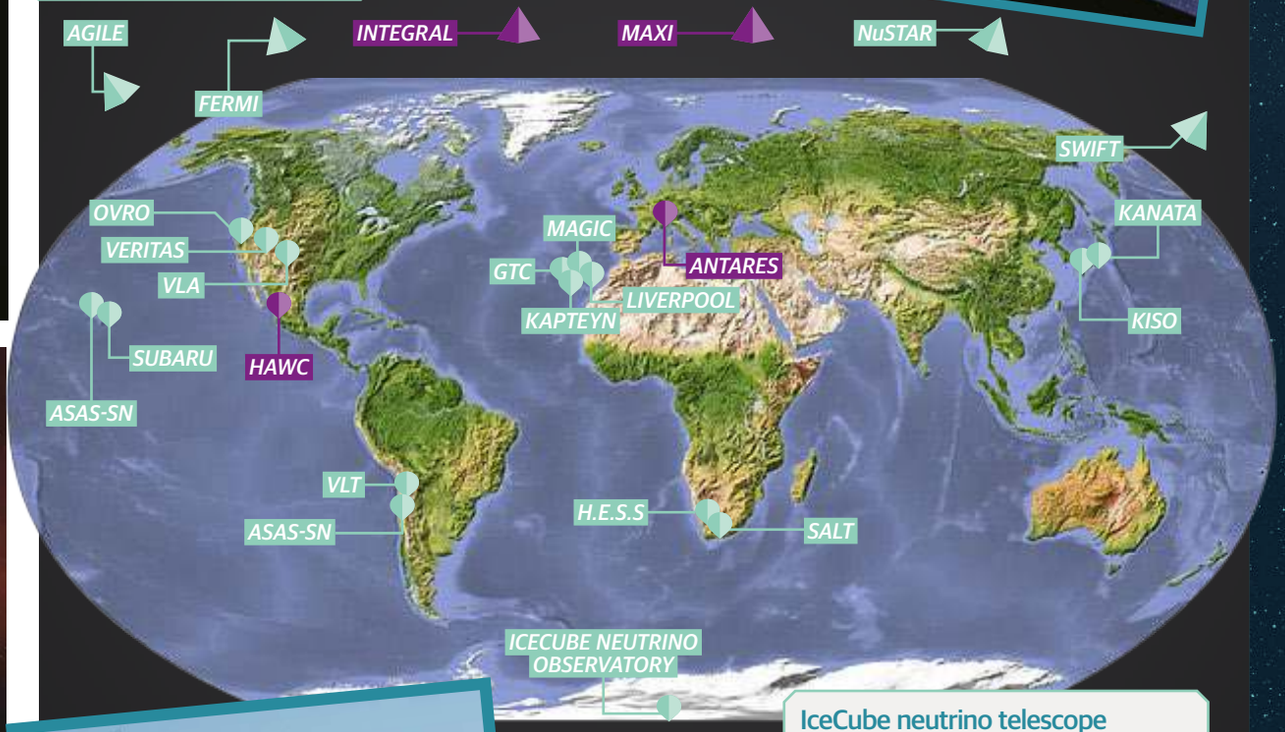
La Palma, Spain

The twin MAGIC telescopes are located 2,200 metres (7,218 feet) above sea level. They detect the particle showers released when gamma rays interact with particles in Earth's atmosphere. MAGIC confirmed Fermi's findings by detecting even higher energy gamma rays from blazar TXS 0506+056.

Fermi Gamma-ray Space Telescope

Earth orbit

NASA's Fermi Gamma-ray Space Telescope (FGST) is a space-based telescope designed to detect high-energy gamma rays emitted by pulsars and active galactic nuclei. Fermi was the first to identify that the source of the neutrinos was blazar TXS 0506+056.



Very Large Array (VLA)

New Mexico, US

The VLA is a collection of 27 radio antennae, each with a diameter of 25 metres (82 feet), in New Mexico. The VLA was one of about 20 other telescopes to confirm that the blazar was emitting huge amounts of radiation across the electromagnetic spectrum.

Observatories

Earth observatory

Space observatory

Detections

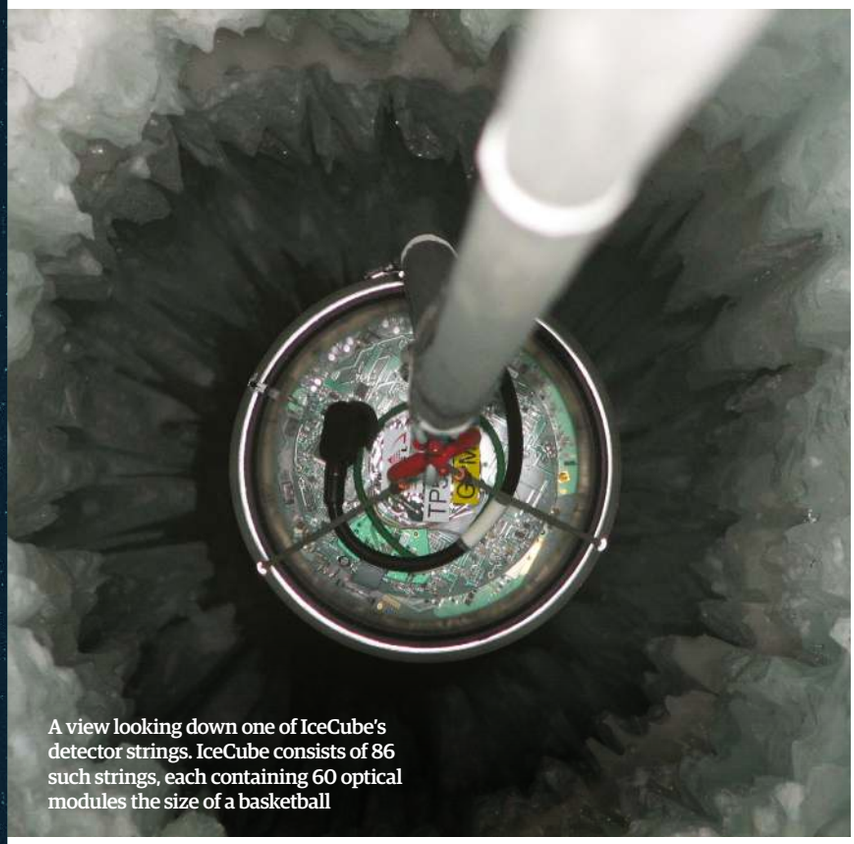
Observations with detection

Observations without detection

IceCube neutrino telescope

South Pole

The IceCube detector is buried beneath the Antarctic ice and extends to a depth of about 2.5 kilometres (1.6 miles). It is made up of an array of over 5,000 sensors that are designed to detect the faint trail of light emitted when a neutrino collides with an atom in the ice. By tracing this trail backwards IceCube was able to identify the region of space the neutrino came from.



A view looking down one of IceCube's detector strings. IceCube consists of 86 such strings, each containing 60 optical modules the size of a basketball

What the ghost particle tells us

They solve a 100-year-old mystery

The source of high-energy cosmic rays has been one of astronomy's greatest mysteries. Neutrinos are created along with the other particles that make up cosmic rays and, because they are impervious to magnetism and gravity, they tell us where cosmic rays come from.

They break the rules

Because they can spontaneously change mass, or flavour, on the fly, neutrinos seem to break the rules that describe nature at its most fundamental. Figuring out how neutrinos do this could help physicists develop new theories.

They are uncorrupted

Unlike almost every other particle, neutrinos can travel through space without being blocked by clouds of dust, stars, planets or even galaxies. Any information they carry will be totally uncorrupted.

They could tell us why anything exists at all

After the Big Bang, matter and anti-matter were created in equal measure and, as such, should have obliterated each other. The fact that anything exists shows that for some reason matter won out. Could the neutrinos strange mass-changing abilities have tipped the scales and allowed matter to win?

Neutrinos are cosmic ghosts

They possess almost no mass and carry no electric charge. They don't interact with matter and are impervious to magnetic fields.

How to chase a neutrino

It's no easy task to catch a cosmic ghost-like particle and it is even harder still to pinpoint exactly where it came from. This is how it was done

1. Set the trap

The IceCube neutrino detector is buried about 2.5 kilometres (1.6 miles) beneath the ice at the South Pole and is about a square kilometre in size. When a neutrino interacts with an atom in the ice it creates a particle called a muon that emits a trail of blue light. On 22 September 2017, IceCube's detectors measured just such a signal.

This is where our ghost comes in. Fortunately, the very same processes that create these high-energy, charged particles also create another, more sober particle along with them: the neutrino. Neutrinos are particles that possess almost no mass and have no electric charge. They barely interact with normal matter and can pass through even the most massive objects as if they weren't there – they travel like a ghost. These properties allow neutrinos to travel undisturbed through the cosmos – influenced by neither magnetic fields, gravity or by any planet that might get in their way. Neutrinos always travel 'as the crow flies', so, if you can detect a neutrino, you only have to trace its trajectory back to find its source.

Unfortunately the very ghost-like properties that allow neutrinos to travel unchecked through space also make them fiendishly difficult to catch here on Earth. For that you need a very special kind of trap.

IceCube, is a most peculiar sort of telescope. It has no mirror to collect light and no lens to focus it. There is no eyepiece to squint through and there is no dish to collect signals from beyond the dark horizon. Instead the IceCube detector is made up of an array of light-detecting sensors, arranged like strings of fairy lights and buried in frozen boreholes over two kilometres (1.2 miles) beneath the South Pole. Each string contains 60 optical modules vertically spaced 17 metres (56 feet) apart, and there are 86 strings set 125 metres (410 feet) apart. IceCube consists of 5,160 sensors encased in a cubic kilometre of solid ice. But, if you can't see a neutrino, what is it looking for?

We are bombarded by them

Neutrinos are the second-most common particle in the universe (after photons). Every single second, about 100 trillion neutrinos pass through your body.

Although countless trillions of neutrinos travel unimpeded past the hydrogen and oxygen atoms that make up the ice surrounding the detectors, every so often a neutrino will collide with one of these atoms. When it does so, the collision causes the atom to spit out a tiny particle called a muon (a sort of heavy electron), which continues along the same path as the neutrino.

This muon will actually be travelling faster than the local speed of light, which, although it cannot be exceeded in a vacuum, is slower when measured travelling through ice. When it does so, just as an aircraft emits a sonic boom when it passes the sound barrier, it emits a sort of 'photonic boom' in the form of a trail of blue light known as Cherenkov radiation.

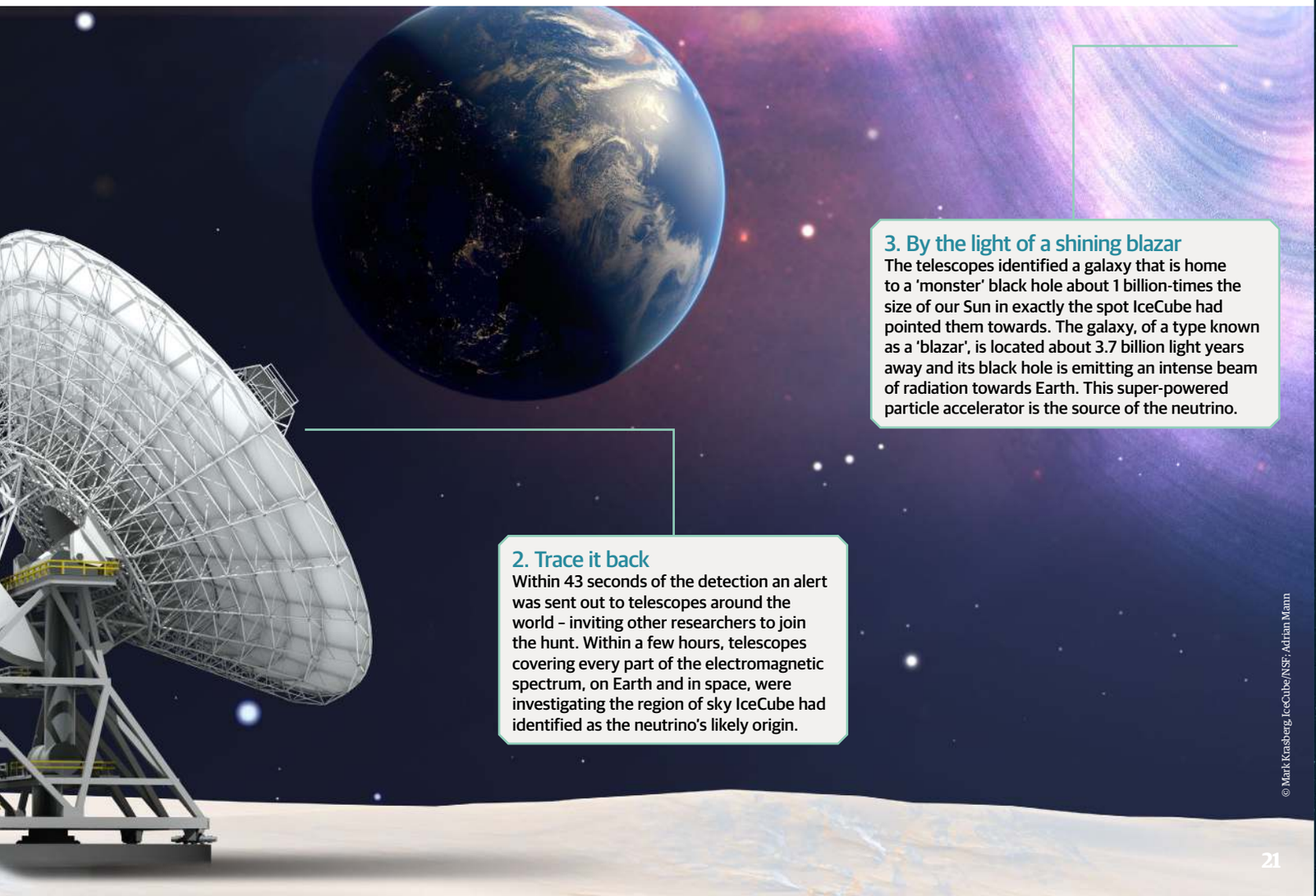
"IceCube measures this trail of light," explains Professor Albrecht Karle, IceCube's associate director for science and instrumentation. "We can do that quite precisely so that we can measure the direction of the neutrino's track."

IceCube detects muons all the time, but these are generally traced back to low-energy muons that are produced in the Earth's atmosphere by cosmic rays. Since 2013, several extremely energetic neutrinos have registered on IceCube's sensors, but they have been frustratingly difficult to trace back to a single celestial object.

Then, on 22 September 2017, a single extremely energetic neutrino was detected by IceCube's sensors. When scientists retraced its path, it pointed them towards a patch of sky near to the constellation of Orion. But that was as much as IceCube alone could tell them – to investigate further, scientists would need to recruit a team of telescopes to probe that area of sky.

Just 43 seconds after making the detection IceCube had broadcast an alert that rallied

"Pinpointing the first source of cosmic rays was only possible because of a multi-messenger campaign" **Prof Francis Halzen**



2. Trace it back

Within 43 seconds of the detection an alert was sent out to telescopes around the world – inviting other researchers to join the hunt. Within a few hours, telescopes covering every part of the electromagnetic spectrum, on Earth and in space, were investigating the region of sky IceCube had identified as the neutrino's likely origin.

3. By the light of a shining blazar

The telescopes identified a galaxy that is home to a 'monster' black hole about 1 billion-times the size of our Sun in exactly the spot IceCube had pointed them towards. The galaxy, of a type known as a 'blazar', is located about 3.7 billion light years away and its black hole is emitting an intense beam of radiation towards Earth. This super-powered particle accelerator is the source of the neutrino.

Artist's impression of a blazar showing the torus of dust around a supermassive black hole. This material is accelerated by the black hole to form twin jets of radiation

astronomers from all over the world, relaying them the coordinates for follow-up observations across the electromagnetic spectrum.

Within four hours of the alert sent out by IceCube, NASA's space-based Neil Gehrels Swift Observatory identified an object as a possible source. This object was a blazar located some 3.7 billion light years from Earth, with the rather catchy name TXS 0506+056.

"A blazar is an active galaxy that contains a black hole," Janet Conrad, professor of physics at MIT and member of the IceCube Collaboration, explains to **All About Space**. "The black hole is spinning quickly, powering jets of particles and photons that spurt out the bottom and top."

Most galaxies have a supermassive black hole at their centre that can have the mass of millions or even billions of Suns. In some galaxies these black holes syphon up material from the disc of gas and dust that surrounds them – accelerating the particles and spewing them out from their poles as concentrated beams of matter travelling at close to the speed of light. Scientists call this a quasar. But when the galaxy is orientated so that its jets point towards Earth, it is called a blazar.

"What's special," says Karle, "is we are in the beam. It is pointing at us. So we are really in the line of fire. We are starring into the eye of the monster, so to speak."

Soon after Swift's observation, the Fermi Large Area Telescope reported that this blazar was indeed flaring – emitting a huge amount of high-energy gamma rays in a beam towards Earth. This was followed up by the ground-based telescope, MAGIC, which reported it had observed even higher energy gamma rays from the same source. Finally, over the course of the next 14 days, reports came in from more than 20 other telescopes, including optical, radio and X-ray, who had recorded a surge in electromagnetic emissions across the spectrum.

With all the evidence pointing to blazar TXS 0506+056, the IceCube researchers searched through their archives for any supporting data. The search paid off, and they identified 13 neutrino signals detected between 2014 and 2015 that also came from the same spot.

"The neutrino flare in our archival data became independent confirmation," Karle explains. "Together with observations from the other observatories, it is compelling evidence for this blazar being the source of extremely energetic neutrinos, and thus high-energy cosmic rays."

It seemed that after more than a century of searching, scientists had finally identified the source, or one source at least, of the mysterious cosmic rays. IceCube may have made the initial detection, but it required the collaboration of dozens of other observatories – an approach called 'multi-messenger astronomy' – to fill in the other pieces of the puzzle.

"Pinpointing the first source of cosmic rays was only possible because of a multi-messenger campaign involving astronomical telescopes operating in all wavelengths of the electromagnetic spectrum," says Professor Francis Halzen, IceCube's principal investigator.

So, has the mystery of the origin of cosmic rays finally been solved?

"It's a pretty amazing finding," says Spencer Klein, member of the IceCube Collaboration, "but more data is needed. The multi-messenger campaign was based on one neutrino. It's great to know about one [source], but we have a ways to go before we have a systemic understanding."

The ability to detect neutrinos will be the latest addition to what is being called a new era of multi-messenger astronomy in which light (or the electromagnetic spectrum) is no longer the only way to collect information from the heavens.

The detection of gravitational waves in 2015 opened up a window that would allow astronomers to observe the collisions of black holes or neutron stars. Being able to reliably track neutrinos to their source would allow astronomers to investigate the physics behind the most extreme cosmic environments. By combining the information we can gather from light, gravitational wave and neutrino observation astronomers will be able to study the universe like never before.

Ghost particles change their identity

There are three types of neutrino – or 'flavours' as physicists call them – the electron neutrino, tau neutrino and muon neutrino, each with a slightly different mass. They can change flavour as they travel through space, 'oscillating' from one mass to another.

"It's great to know about one [source], but we have a ways to go before we have a systemic understanding" **Spencer Klein**

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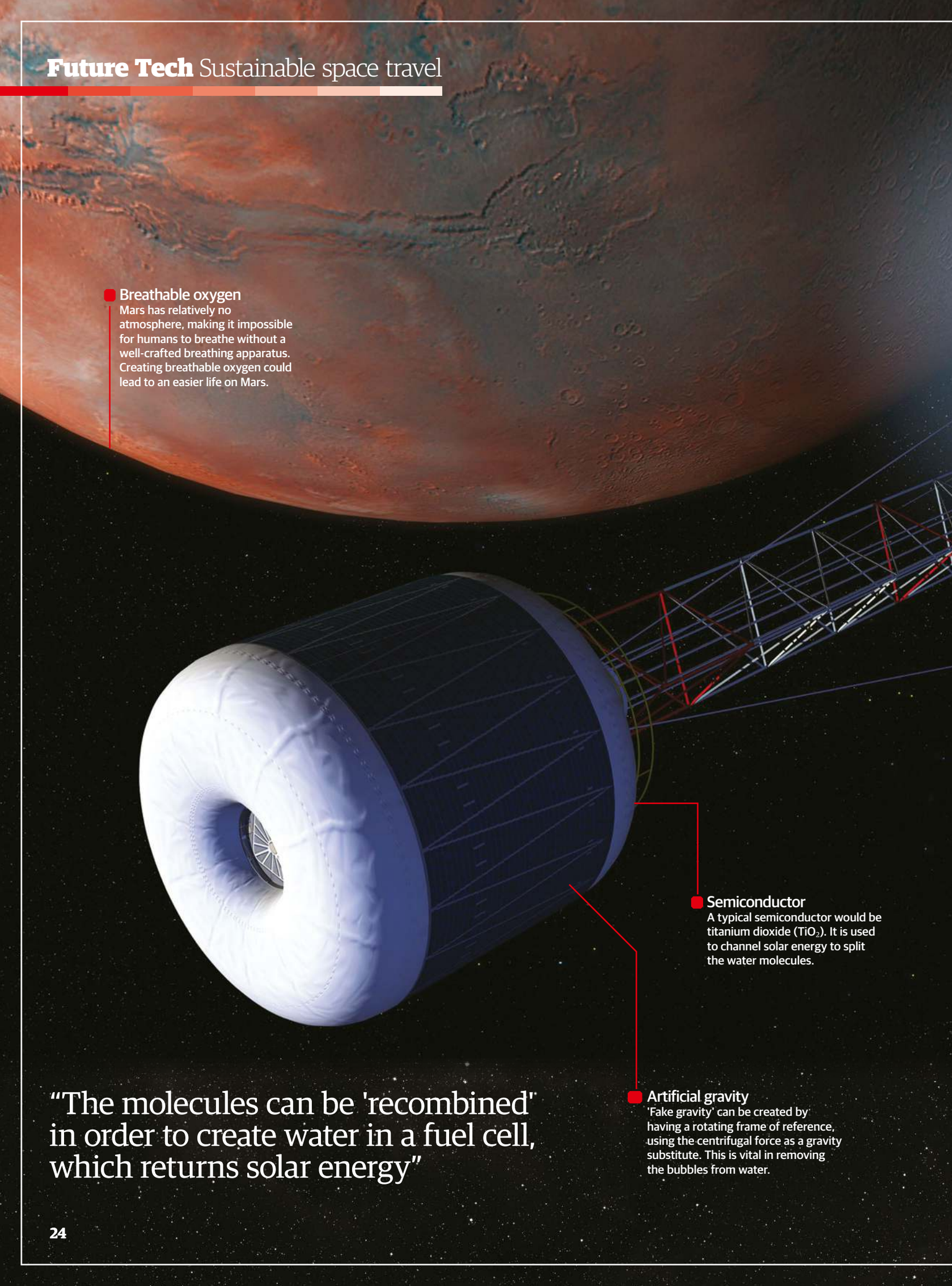
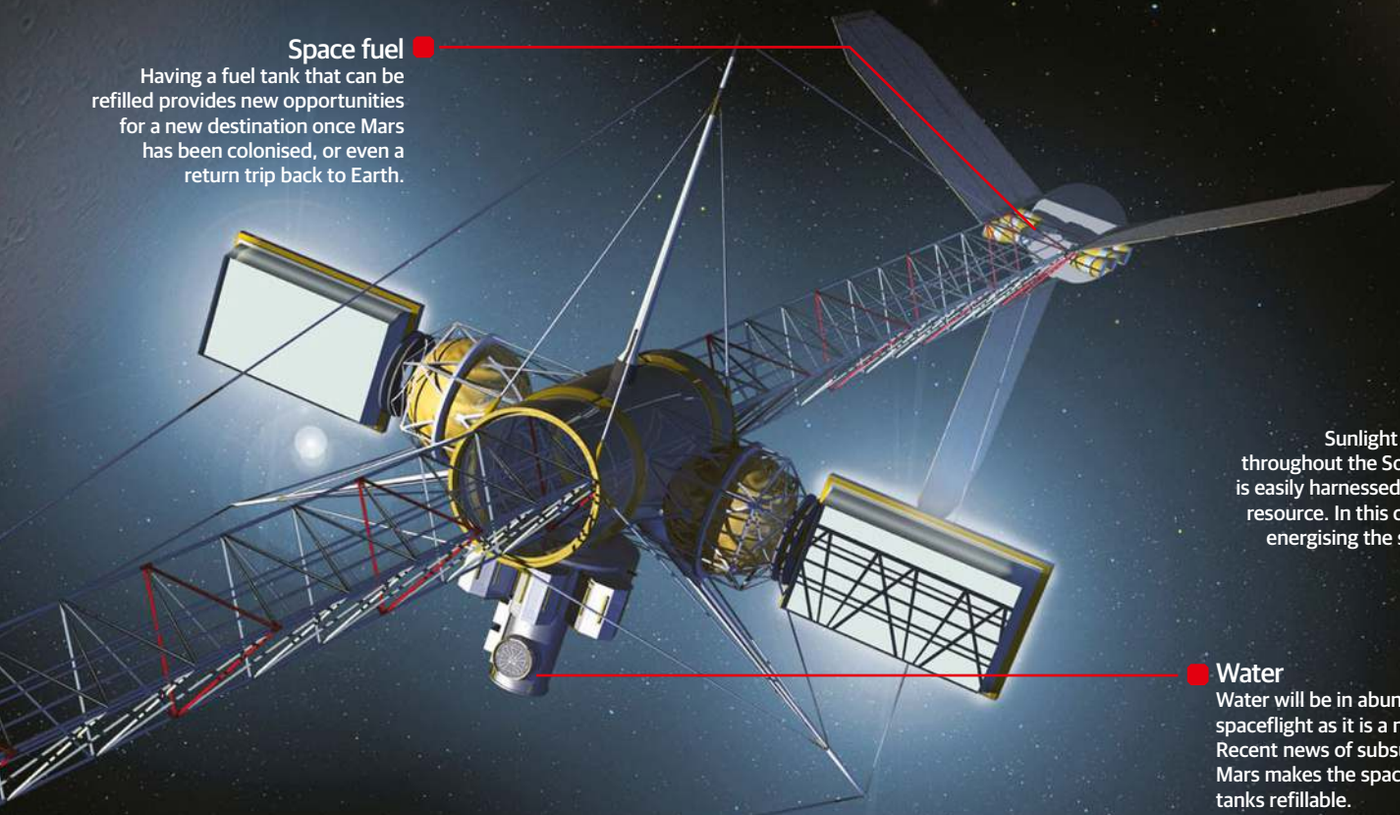


Breathable oxygen
Mars has relatively no atmosphere, making it impossible for humans to breathe without a well-crafted breathing apparatus. Creating breathable oxygen could lead to an easier life on Mars.

Semiconductor
A typical semiconductor would be titanium dioxide (TiO_2). It is used to channel solar energy to split the water molecules.

Artificial gravity
'Fake gravity' can be created by having a rotating frame of reference, using the centrifugal force as a gravity substitute. This is vital in removing the bubbles from water.

"The molecules can be 'recombined' in order to create water in a fuel cell, which returns solar energy"



Space fuel
Having a fuel tank that can be refilled provides new opportunities for a new destination once Mars has been colonised, or even a return trip back to Earth.

Sunlight
Sunlight is ever-present throughout the Solar System and is easily harnessed into a valuable resource. In this case it is vital to energising the semiconductor.

Water
Water will be in abundance in any spaceflight as it is a necessity for life. Recent news of subsurface water at Mars makes the spacecraft's water tanks refillable.

Sustainable space travel

Creating fuel and breathable oxygen during humanity's voyage through the Solar System and beyond is essential

A new study, recently published in *Nature Communications,* has proposed a new way to manufacture oxygen (to breathe) and hydrogen (for spacecraft fuel) while in space. The idea involves transporting large amounts of water (H_2O) on board the spacecraft, a semiconductor material and the ever-present resource that is sunlight. The idea behind the process is to split molecules of water into their constituent atoms using an electric current.

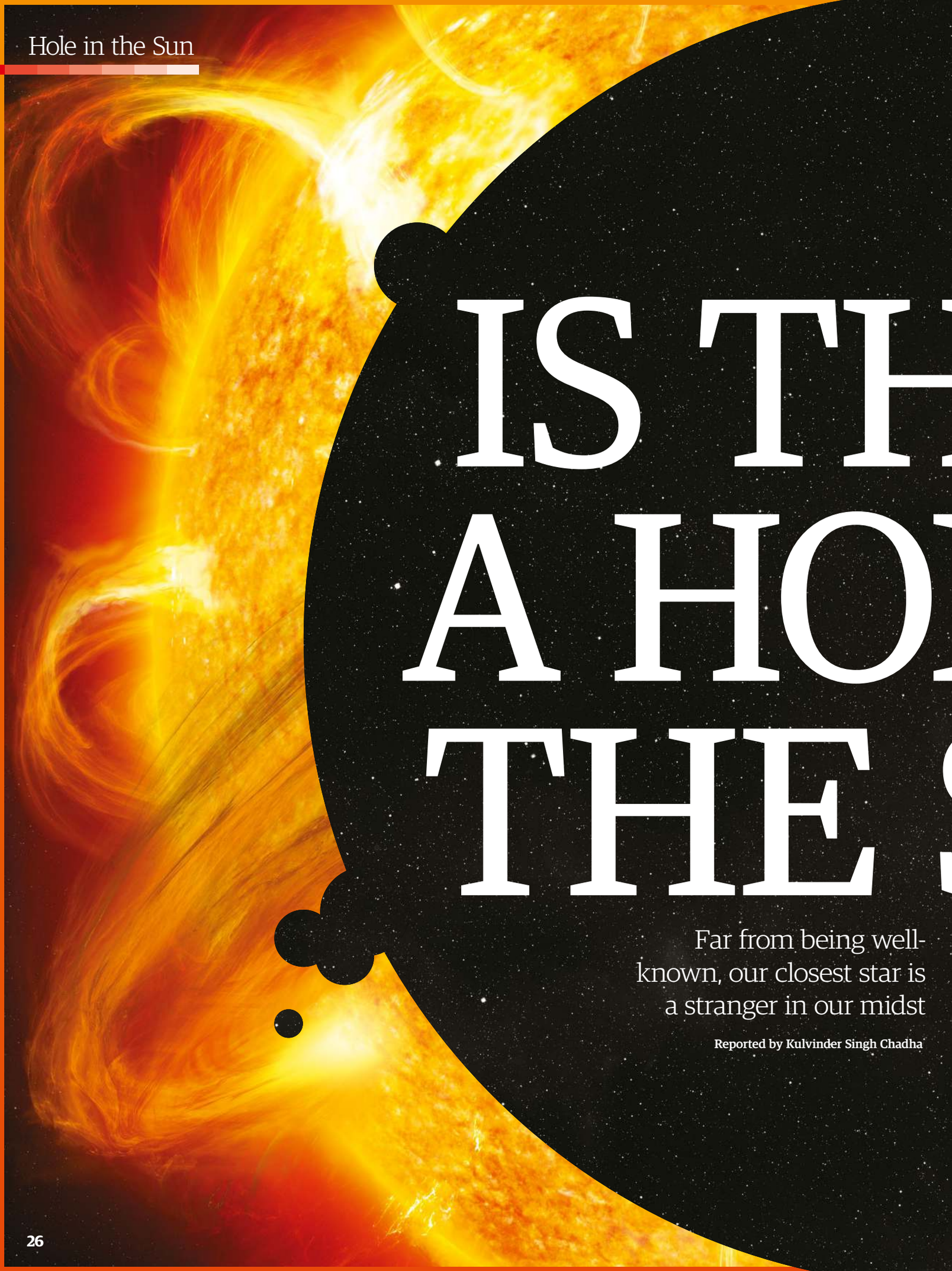
There are two ways of separating water molecules. One way is through a process known as electrolysis, which involves passing an electric current through a water sample containing some soluble electrolyte. This will break down water into hydrogen and oxygen and they are collected at different electrodes. Although this is theoretically possible, the equipment is not readily available and appropriate for spaceflight as of yet.

The method proven more appropriate for spaceflight is a process called 'photocatalytic water splitting'. In this scenario, a semiconductor is inserted into the water and absorbs photons, which gives enough energy to an electron on the semiconductor to jump and leave a hole. This free electron can then interact with protons to form hydrogen, whereas the hole absorbs electrons from the water to form protons and oxygen.

This process can also be reversed, and the molecules can be 'recombined' in order to create water in a fuel cell, which returns solar energy. The idea that three vital elements for long-term space travel – water, hydrogen and oxygen – can be used and created in a sustainable way is tantalising. The only issue with this is what to do with the bubbles.

The researchers wanted to test the viability of the photocatalysis in space by setting up an experiment down a 120-metre (394-foot) drop tower. With an object in freefall, gravity is essentially nonexistent, creating the perfect environment to test experiments without actually going to space. During the drop the researchers showed it is possible to split the water, but there is a problem with the bubbles that are created.

When bubbles are created on Earth, gravity automatically makes sure the bubbles rise to the top and dissipate. In space the bubbles do not know where to go and permeate the water. If the bubbles were to stick on the catalyst, there would be no free room for the next bubble to form. The researchers combated this problem by creating pyramid-shaped zones where the bubbles could easily be released from the catalyst. However, there was still a problem with the evacuation of bubbles from the liquid. To prove viable there needs to be artificial gravity, as it will provide the force needed to evacuate the bubbles from the water.



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Far from being well-known, our closest star is a stranger in our midst

Reported by Kulvinder Singh Chadha

HERE LE IN SUN?

It may be the brightest object in our sky, but the Sun is a dark horse. The more we study it, the more quirks it reveals and recently we have found quite a fundamental one. A new way of modelling the Sun's atmosphere has further widened a gap in our knowledge of its core. This could have implications for the whole of astrophysics, not just the Sun, and it may mean having to rethink a whole century of solar physics. The age, mass and luminosity of billions of stars would have to be recalculated.

Scientists from the Max Planck Institute of Astrophysics (Aldo Serenelli and Martin Asplund), Yale University (Sarbani Basu) and Wichita State University (Jason Ferguson) formulated a new

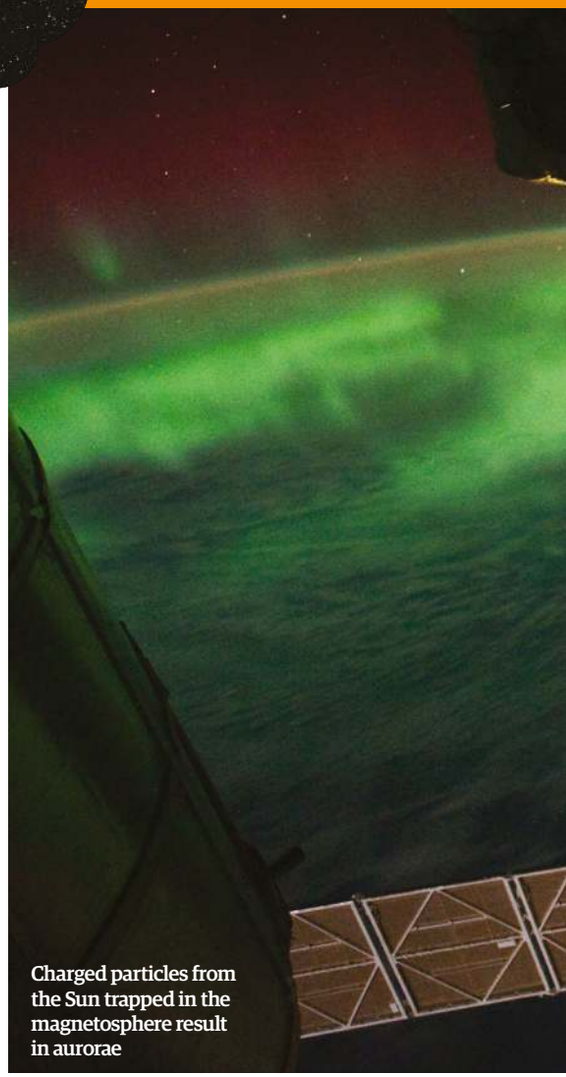
model of the Sun's surface, its photosphere, that was dynamic and three dimensional. Previous models had been static and one dimensional. In stars, elements heavier than helium are called 'metals' by astrophysicists whether they're metallic or not. The 1D models had a higher proportion of these than the 3D one found was required. Some have put forward the idea that this means that a certain amount of mass has 'gone missing' from the Sun; up to 1,500 Earths' worth.

However, one of the scientists involved in the work, Dr Tiago Pereira of Oslo University has poured cold water on this notion. "I find the idea of missing mass in the Sun to be ridiculous. Some people have made models of the solar interior. Those models are incomplete and lead to more mass than observed. This doesn't mean anything is missing, only our knowledge is incomplete."

Until the early 20th century no one really knew what powered the Sun's interior. British scientist Lord Kelvin and the German scientist Hermann von Helmholtz both proposed that a ball of gas of the Sun's size could efficiently generate heat by contracting under its own gravity. The figure calculated by Kelvin in 1862 came to 100 million years; far shorter than the 300 million year-estimate of Earth's age by geologists of the time. But Kelvin also knew the limits of knowledge of the Sun's processes at that time, saying in March's *Popular Lectures and Addresses, volume 1, 2nd edition*: "Mutual gravitation between the different parts of the Sun's contracting mass must do an amount of work, which cannot be calculated with certainty, only because the law of the Sun's interior density is not known." So this couldn't be the way the Sun powered itself.

It wasn't until Einstein published his work on special relativity in 1905 that the true mechanism was discovered. Deriving the equation $E=mc^2$ from his work, Einstein showed that mass and energy were two sides of the same coin, and that a small amount of mass could be converted into enormous amounts of energy. This was the foundation on which scientists from the 1920s to the 1950s formulated stellar nuclear fusion equations. They showed the Sun is powered by hydrogen nuclei (74.9 per cent of its mass) fusing into a heavier element, helium (23.8 per cent of its mass), and releasing energy in the process. The other 1.3 per cent is heavier elements – the 'metals' – such as oxygen, carbon and magnesium. 4.25 million tonnes of mass are converted directly into energy every second in the core, making the Sun shine. That may sound like a lot, but it only amounts to 0.15 per cent of Earth's mass since dinosaurs died out around 66 million years ago.

But that isn't the end of the story. The 3D model was tested against the latest spectroscopic observations from the Swedish Solar Telescope in La Palma. The results were good, and also in agreement with other spectroscopic data suggesting the scientists were on the right track. But when



Charged particles from the Sun trapped in the magnetosphere result in aurorae

Why's our Sun so odd?

Sometimes it can seem as if it's a confused, hot mess

1. The Sun's siblings are missing
We don't know where the Sun's siblings are. The Australian National Observatory will look at the chemical composition of over 340,000 stars in the Milky Way to find the Sun's 'DNA match'.

2. A hot shower
Just like on Earth, it rains on the Sun. When hot plasma meets cooler parts of the corona, it precipitates back to the surface.

3. Sprung from the solar surface
Helical ultraviolet radiation could act like a spring and propel rare helium-3 and iron in a jet from the solar surface.

4. The corona has structure
Denoising coronagraph images reveals that the outer corona has a turbulent, dynamic structure that may explain its 100-times temperature excess near Earth.

5. Gamma rays do what they like
There's a dip in the Sun's gamma-ray energy level between 30 to 50 GeV. This is a new discovery and the mechanism for it is entirely unknown.

6. Microscopic crystals reveal the Sun's history
Primordial hibonite crystals show the Sun's unstable early history. Charged particles from the protosun struck the hibonite, forming helium and neon.

"The problem is most likely with our incomplete knowledge of processes in the core of the Sun"
Tiago Pereira

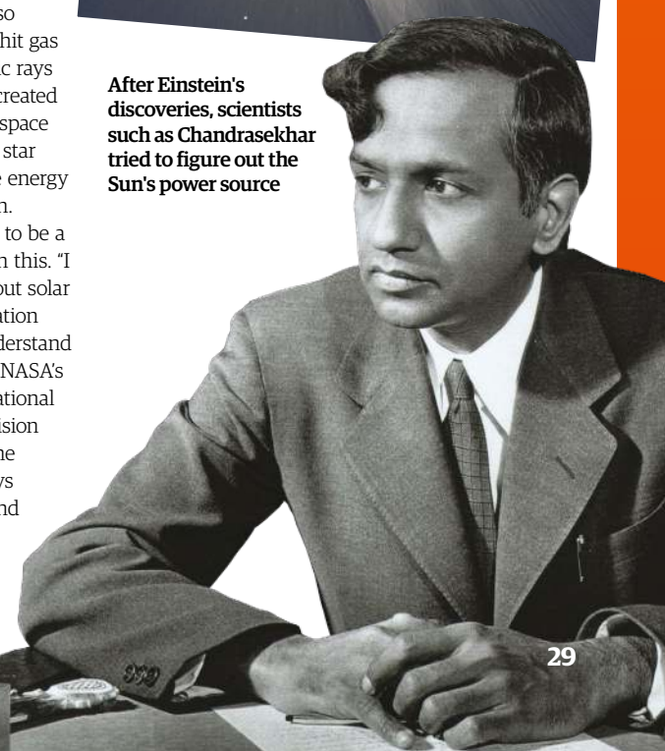
compared with helioseismology data – a method of studying the Sun's core region using sound and pressure waves, similar to seismology on Earth – there was a mismatch. The vast majority of the information we derive from the Sun comes from its atmospheric regions, whereas helioseismology accounts for the rest. One-dimensional helioseismology models, not the aforementioned atmospheric ones, reach down to the core but use a 'broad brush' approach. Observations show these models to be really poor, but adding the updated solar metallicity values makes them three-times worse. This doesn't mean that the 3D model or helioseismology are wrong, however.

As Pereira says, "The problem is most likely with solar interior models and our incomplete knowledge of processes in the core of the Sun." By this he means macroscale structure and processes like convection, but also microscopic processes investigated by Eddington, Hoyle and others, such as the absorption of radiation and neutrinos by atoms at different temperatures and pressures.

Another recently discovered strange feature could help in solving the core's mysteries. The Sun appears to have not one, but two types of gamma-ray emission. Another team of astronomers from Ohio State University, the Weizmann Institute of Science and Nanchang University looked back over a decade's worth of data from NASA's Fermi Gamma-ray Space Telescope. Although primarily created to observe gamma-ray emissions from astrophysical objects such as pulsars, cosmic jets and active galaxies, Fermi also showed dual-component gamma-ray emissions from the Sun. Between 2008 and 2009, centring on the solar minimum, bright emissions were dominant at the solar equator, with an added polar component. Between 2010 and 2017, centring on the solar maximum, the gamma-rays mostly came from the poles. Dr Tim Linden of the Ohio State University says, "In 1991, a paper by Seckel, Stanev and Gaisser showed that cosmic-ray protons that hit the Sun's surface could be turned around by magnetic fields, acting like a mirror. The protons [originally moving in towards the Sun] would instead move outwards and then produce gamma-rays [also moving outwards from the Sun] when they hit gas in the solar atmosphere." High-energy cosmic rays – which are actually charged particles – are created and accelerated by powerful events in deep space such as supernovae explosions and neutron star collisions. This doesn't, however, explain the energy levels observed in the Fermi data for the Sun.

Does this mean the Sun has the potential to be a giant cosmic-ray detector? Linden is sober on this. "I think we would need to learn a lot more about solar magnetic fields affecting cosmic-ray propagation before we could utilise the Sun to better understand cosmic rays themselves." He points out that NASA's Alpha Magnetic Spectrometer on the International Space Station is already obtaining high-precision measurements of cosmic rays near Earth. The study of cosmic-ray-created solar gamma rays could potentially help scientists to understand the Sun's magnetic fields, who's origin isn't entirely known, as well as cosmic-ray propagation in regions with very different

The solar corona is the Sun's extended outer atmosphere – seen here during a total eclipse



After Einstein's discoveries, scientists such as Chandrasekhar tried to figure out the Sun's power source

Our angry star

The Sun interacts with the Solar System in many different ways

8. The outer bounds

At about 120-times the Earth-Sun distance, the solar wind stops abruptly. Detected by NASA's Voyager 2 probe, this termination shock is considered the start of interstellar space.

7. Cause a conundrum

As the closest planet to the Sun, Mercury's orbit can't be explained by Newton's physics. It takes Einstein's general theory of relativity to offer a solution.

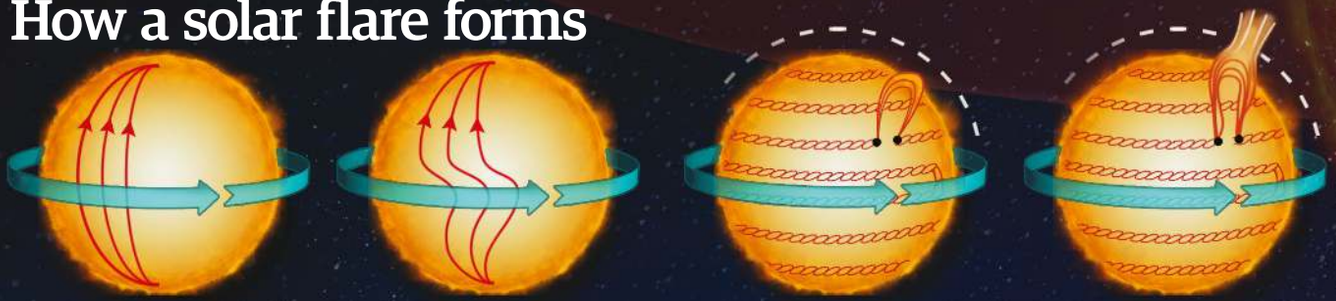
3. Mangled magnetic mix

The Sun's magnetic field traps plasma, but can also contort until it 'snaps', sending charged material flying into space as a coronal mass ejection. This causes aurorae.

5. Shine bright like a flare

Solar flares are bursts of electromagnetic activity that may be accompanied by coronal mass ejections. If one occurs in a coronal hole there's nothing to stop the material firing into space.

How a solar flare forms

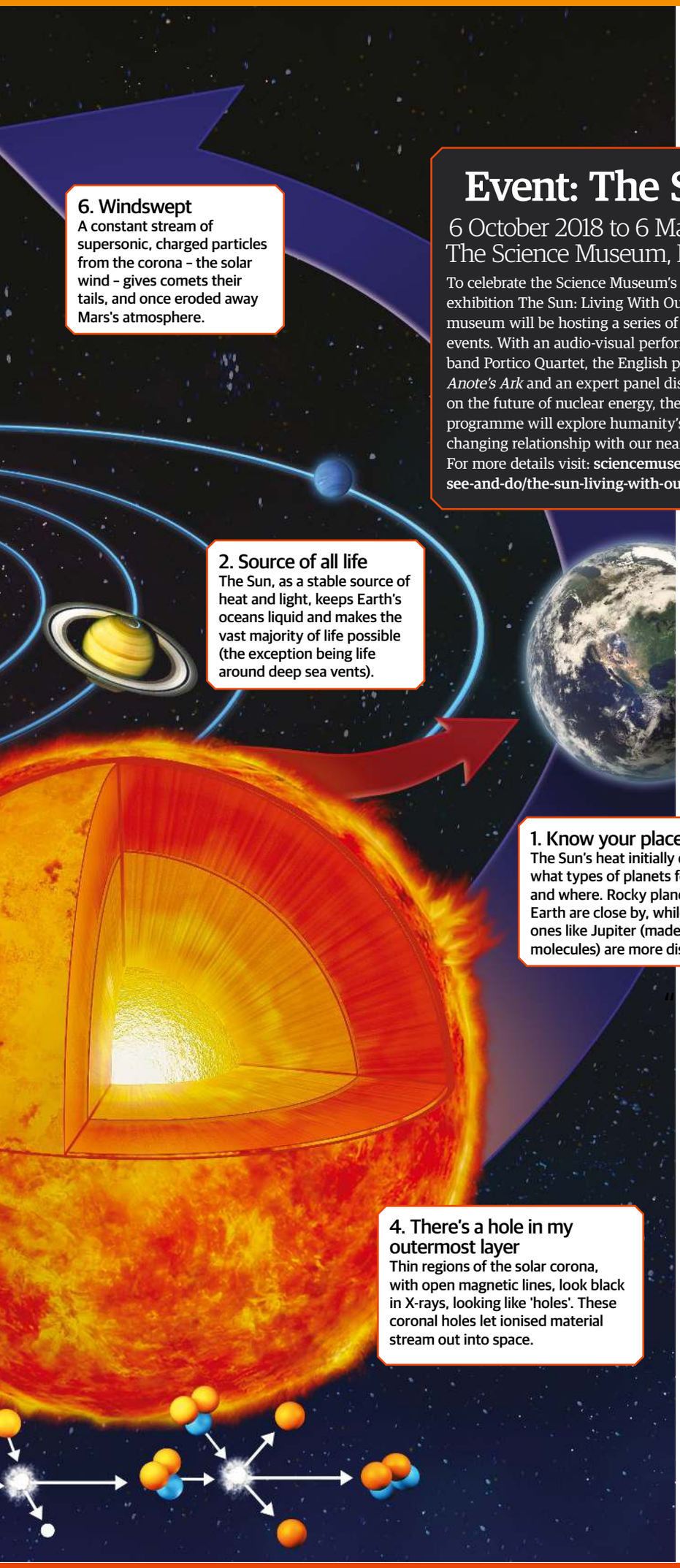


Magnetic field lines
The Sun's lines run from south to north. Solar flares are classified according to their brightness in X-ray.

Stretched field lines
The Sun's rotation causes field lines to stretch, more so at the equator, which rotates faster than at the poles.

Twisted field lines
Field lines become twisted, causing some of them to eventually burst through the surface to form loops.

Solar storm
The loop grows past a critical point, blasting away from the Sun's surface and forming a solar storm.



Event: The Sun

6 October 2018 to 6 May 2019
The Science Museum, London

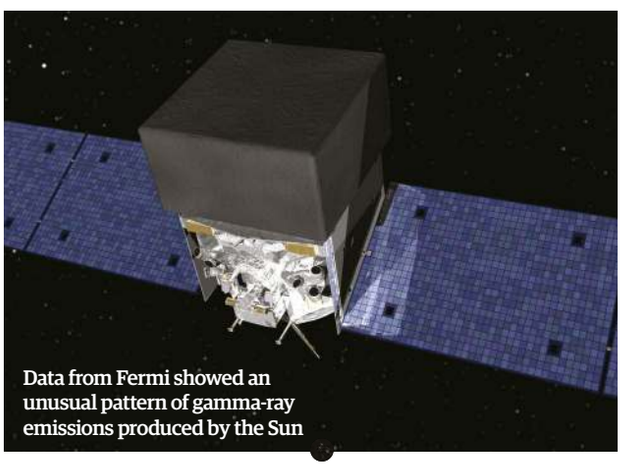
To celebrate the Science Museum's blockbuster exhibition The Sun: Living With Our Star, the museum will be hosting a series of unique events. With an audio-visual performance by band Portico Quartet, the English premiere of *Anote's Ark* and an expert panel discussion on the future of nuclear energy, the events programme will explore humanity's ever-changing relationship with our nearest star. For more details visit: **sciencemuseum.org.uk/see-and-do/the-sun-living-with-our-star**

magnetic structures than near the Earth. "In particular, we believe that the gamma-ray emission is produced several hundred kilometres deep within the Sun's photosphere, which is a region that's particularly hard to probe," Linden says.

Finally, from the photosphere we go all the way out to the Sun's extended outer atmosphere, the corona, for the strangest features of all. The fact that the corona is up to 500-times hotter than the Sun's surface isn't new. The coronal heating problem has been known about since the 19th century, and many theories try to explain it. The eerie-looking corona, which can be viewed from Earth during a total solar eclipse, or by spacecraft such as NASA's Solar and Heliospheric Observatory (SOHO), is a million-times dimmer than the Sun's surface, but because Earth's surface atmosphere is around two billion billion-times as dense – the corona being up to only ten atoms per cubic centimetre – there's very little heat in the corona, despite its temperature.

What hasn't been known until now is that the Corona has a hidden structure. Dr Craig DeForest from the Southwest Research Institute and his team 'denoised' images of the upper, cooler parts of the solar corona using NASA's Solar Terrestrial Relations Observatory (STEREO). He adds, "The work we did involves the corona at quite high altitudes, well above where most of the coronal heat is." By looking at this region the team uncovered something. "By revealing that the outer corona is very highly structured, we believe we've found an energy reservoir large enough to explain a related heating problem – the solar wind heating problem." The solar wind near the Earth can be between 100,000 to 1,000,000 degrees Celsius (180,032 to 1,800,032 degrees Fahrenheit) when it should be closer to 2,500 degrees Celsius (4,532 degrees Fahrenheit). DeForest says that the most exciting thing will be seeing how this large-scale structure will compare with the fine detail that will be measured by NASA's Parker Solar Probe, which launched on 12 August.

> "We believe we've found an energy reservoir large enough to explain a related heating problem" **Craig DeForest**



Data from Fermi showed an unusual pattern of gamma-ray emissions produced by the Sun

INTERVIEW BIO

Seth Shostak

A high-profile name in the search for life outside of Earth, Seth has been the senior astronomer for the SETI Institute since 2001. Before his involvement with them he worked with radio telescopes in The Netherlands and the US, trying to investigate the ultimate fate of the universe by studying galaxy motion.

As well as his work in radio astronomy, Shostak also hosts SETI's weekly radio show, *Big Picture Science*, and has worked on television documentaries. In 2015 he was awarded The Carl Sagan Prize for Science Popularization for his contributions.

How we'll talk to alien life

The Search for Extraterrestrial Intelligence (SETI) is one of the most exciting topics in all of astronomy, but what are the different ways we might receive messages from ET – and what language could we use to strike up a conversation? We caught up with leading SETI researcher Seth Shostak

Can you tell us a little about your background and how you first got involved in the SETI field?
I'm the senior astronomer and also an Institute fellow here at the SETI Institute. I've been here for about 24 years, so it's the longest job I've ever had. I got here kind of accidentally – I studied radio astronomy and spent quite a bit of time studying galaxies with radio telescopes, including 13 years in Holland. I wasn't doing SETI at the time, but I was certainly interested in it, as it's the same technology that we were using to study galaxies; it's just radio astronomy but with a slightly different kind of receiver and obviously a different goal.

After I moved back to the US in 1988 to work with one of my brothers on a software startup that unfortunately failed, I was without a job for about a year. Thankfully, some people here at the SETI Institute, which happens to be located in the same town where I was living [Mountain View, California], heard that I was here, and they simply rang me up and asked if I wanted a job. That was at the time when there was some NASA funding for SETI, so there was more money around!

When most people think of SETI they think of big radio dishes pointing towards the sky, and as you say, your own background is in radio astronomy. Is that the only realistic way that we might receive signals from extraterrestrials?
Radio's certainly not the only game in town, but I think what's actually being done in SETI is always rather restricted by money and resources. You have to make something of a bet and decide what it is you're going to do given whatever money you have. So far that's largely been radio SETI, but there's no doubt there are other ways to look for things.

For instance, both the University of California at Berkeley and we here at the SETI Institute are building equipment that will look for laser flashes. There's been some work in that field for 20 or 30 years, but not much has been done – no one's systematically searched the sky for flashing laser beacons. For example, if tonight some spotlight went off in the Orion constellation for a microsecond – a green flash or something like that – it probably wouldn't be seen. Those sorts of signals could be happening all over the place all the time, but we wouldn't know. So it's a ripe area for investigation and it's time we started looking.

But I guess 90 per cent of the effort is still going to radio SETI. The advantage of radio, of course, is that you can broadcast it. If you have a big laser then you have to decide exactly where you're going to point it, but with radio, you can send it across a broader swath of the sky. Of course if aliens were being thrifty, they could also target the radio transmissions, which is to say aim them in a tighter beam. But perhaps if lasers had been invented before radio, then maybe 90 per cent of today's effort would be dedicated to optical SETI – there's definitely a historical component there.

There seems to have been a surge of interest in the possibility of detecting artificial structures built by alien civilisations. What do you think are the possibilities for that kind of discovery, and how would it compare to deliberate signals?
Artefacts have advantages and disadvantages – the advantage is that if you build something big, you don't have to aim it at anybody; you don't have to deliberately get the attention of somebody else, they might just trip across it. We might be able to find something even though a distant civilisation had no intention of getting discovered. Artefacts are also long-lasting – if you're sending a signal you have to hope that someone's looking in the right direction at the right time.

The disadvantage is that an artefact probably isn't going to be very useful for signalling. Of course if you're talking about aliens with the technology to build a Dyson sphere, then they'd have the ability to send signals, but that depends on their intentions.

As far as sending actual bits of information, then you'd probably rely on optical or radio signals. Optical signals such as laser beams could send more bits per second than radio, but they have their own problems – they might be absorbed or scattered by the interstellar medium, depending on what the wavelength is.

The Allen Telescope Array (ATA) conducts a simultaneous search for extraterrestrial intelligence (SETI)

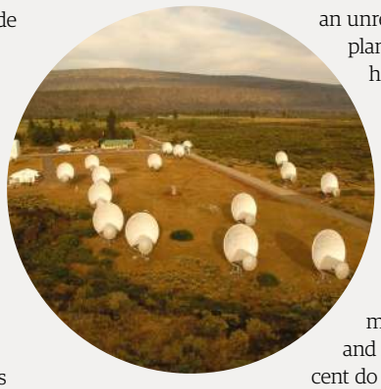
Are there any other hypothetical ways of sending actual messages that don't rely on light or radio?
Some people have suggested neutrinos as a way of communicating. I've never been very keen on the idea – they're very expensive to produce in terms of energy, and so far as we know they're very hard to detect. Having said that, maybe they're only hard to detect for us, and the big advantage is that neutrinos go everywhere – they pass straight through the Earth.

In terms of how much data you could send, there was a paper a good few years ago that pointed out, if your goal is to send the maximum number of bits per second, then the best way of doing that is to load up a bunch of thumb drives, put them in a rocket and send them somewhere. It would obviously take a long time and you have to know where the rocket's going, but you could argue that some of that also applies to other SETI methods...

People write me all the time talking about gravitational waves, but I'm not sure. Gravitational waves are very hard to produce and hard to detect and I can't see any real advantage over neutrinos. You can't encode a lot of bits of information by colliding a pair of neutron stars together!

When we're talking about sending messages, we naturally fall into terminology that we use when talking about signals on Earth – do those terms really make sense when talking about communicating with alien civilisations?
Well some people would say that talking about binary and bits as an encoding scheme is maybe too anthropocentric, but I don't think so. With binary all you have to do is decide 'is the signal there, or is it not there?'. If you try some other sort of encoding, such as analogue with many different gradations, then you either have to detect many different levels of signal for traditional AM radio or, for signals such as FM or spread-spectrum, you need some kind of knowledge of the parameters used for the signal encoding.

"Most of my colleagues don't really care much about what the aliens might look like so long as they can build that transmitter"



There are many different ways of sending information, but binary just happens to be the simplest. You can see that in the development of radio. Morse code was the first way of sending information – essentially just turning the transmitter on and off in a pattern. That's the easiest thing to do and it's also fairly noise tolerant – any signalling channel will always have noise, and so having a system that doesn't get affected so much by the signal-to-noise ratio has advantages.

I don't think binary is any more anthropocentric than saying you might send pictures in a 'raster grid' of pixels. Some people might argue that's what humans do, but aliens might send pictures by vector descriptions [describing lines by their direction and length]. And maybe that's what they would do among themselves, but if they're trying to communicate with someone else who they don't know anything about, I think they'd probably go for something straightforward.

I guess that brings us to a related question – what can we guess about how other intelligences might think, and how would that affect our attempts to communicate with them?
Well in terms of intelligence, SETI scientists tend to have an operational definition – if you can build a transmitter, you're intelligent. Most of my colleagues here don't really care much about what the aliens might look like so long as they can build that transmitter. I think that's maybe a little simple, because if you look at what we're currently doing in this century with machine intelligence, in some ways we're developing our successors.

Those machines don't have to wait a third of a million years to maybe get a bit more intelligent – they're not stuck with Darwin and can design their own successors, so very quickly we're going to get intelligence that just dwarfs the collective intelligence of all humanity. So very quickly we're going to have these really, really smart machines. I don't know what they'll do – they might just sit around playing FreeCell all day – some of them might leave. I don't think that's an unreasonable assumption – Earthlike planets aren't really places with a high concentration of energy. We get some sunlight, we have fossil fuels and all that, but if you really want energy then you might go to the centre of the galaxy – there's a giant black hole there, and you can harvest a lot of energy out of that. Maybe not all of these machine intelligences will get up and leave, but if just one or two per cent do that, then the consequences could still be that the majority of intelligence in the galaxy would be synthetic.

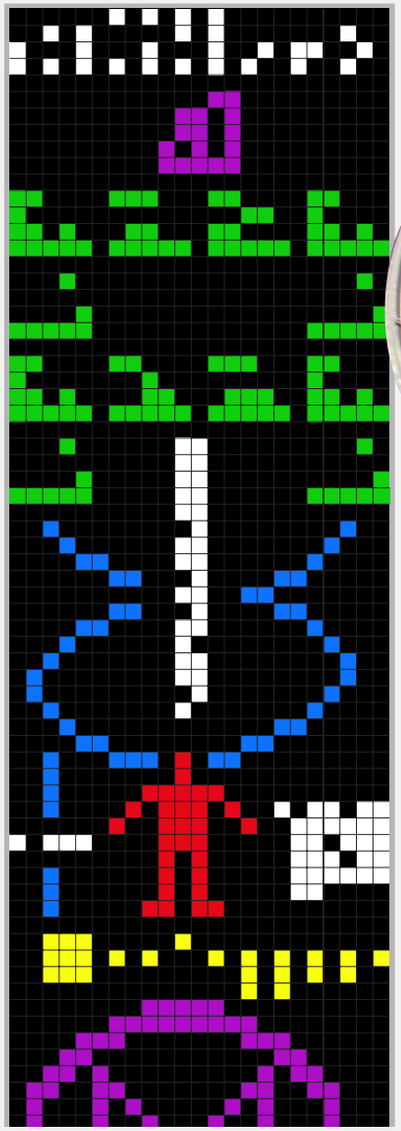
If that's right, then it throws a real monkey wrench into the SETI enterprise, because you no longer know where to point your antennae or look for laser flashes. They might not be coming from stellar systems with the potential for habitable planets as we've always assumed – they could be coming from machines in interstellar space, or maybe the machines simply wouldn't make their positions known. It could be that looking for analogues of ourselves, while it's appealing and certainly the basis for a lot of movies, is maybe like trilobites looking for other trilobites!

So far, if we think of human messages sent to the stars, they've mostly involved pictures. Do you think that's the best way of doing it? And are there any alternatives in terms of finding a 'language' to communicate with aliens?
Well, pictorial communication does assume that the aliens have eyes, but eyes are pretty useful if you're on a planet around a star. All that radiation can give you a lot of information about where to find dinner or a mate or anything else, and even single-celled organisms in the ocean often have some sort of light-sensitivity – it's something that's evolved several times so it seems like a good idea. Communicating with music is something that's shown a lot in movies [he imitates the *Close Encounters* theme], but that's pretty slow and ambiguous if you ask me.

If you say not pictures, then what about mathematics? There's a guy in Holland, Hans Freudenthal, who has developed a whole language based on mathematics called Lincos, short for 'Lingua Cosmica'. He figures if the aliens can build a radio transmitter or laser they'll know mathematics, and math is presumably universal, so they'll understand the relationships in the language. But again, you can convey certain things like inequalities, logic and the Pythagorean theorem, but I don't think it's a great way to communicate – you can't explain everything with mathematics.

So while they're very admirable in their way, I don't think these efforts are really necessary. Think

The SETI Institute and the University of California at Berkeley are developing Optical SETI – a search for laser pulses from distant aliens



The Arecibo message consisted of 1679 binary pulses. The message was directed towards Messier 13 in the hopes that it would be found and deciphered

In autumn 2017, the Allen Telescope Array (ATA) looked for signs of technology on interstellar asteroid 'Oumuamua

In 1974, the giant 305-metre radio telescope at Arecibo, Puerto Rico, was used to send a brief message towards the globular cluster Messier 13, some 25,000 light years away

about how we decoded messages in unknown languages. The canonical example is Egyptian hieroglyphics. In that case we had the Rosetta Stone to make it easier, but if we hadn't found that, they still would have been deciphered – partly because the hieroglyphs were written by other humans, but mostly because there are a lot of them out there. If you look at any inscription or go into any tomb in the Valley of the Kings, or any sarcophagus, there are hieroglyphs everywhere. That's a lot of material, and if you have a lot of material, you can start to look for redundancies, things that repeat and other common features – similar to the way the Enigma codes were cracked during World War II.

So if we did make a concerted effort to contact an alien civilisation, what format do you think the message should take?

Well the famous Arecibo message was really just a demonstration, and while there have been other messages sent since, they've all been rather similar – they're fairly short, lasting for minutes rather than years, and they have to be very easy to decode and don't contain a lot of info.

My suggestion is to send the contents of the Google servers that are located just down the street from us in Mountain View. If we sent the entire Internet, encoded into a simple pictorial form, then it's like the hieroglyphs – there's a lot of material. If the aliens picked up a week's worth of data, they might see the little symbols 'd-o-g' – they don't know English, they don't know the alphabet, but often where they see the symbols they find there's also a picture of this furry animal with four legs and a tail. If they scan through and look for things that recur, then in that very simple way you could learn a whole bunch of nouns.

I'd go for that simple approach rather than trying to do things with music, mathematics or something else. The other approaches are predicated on the idea that the message will be short, but if the aliens are hundreds of even thousands of light years away, it's going to take so long to send and receive signals anyway, you might as well send a lot of stuff!

Finally, I wonder if you have any thoughts about the sceptics who wonder whether the idea of attempting to communicate is really a good idea. And assuming we do, who do you think should be in charge of that communication?

It's actually become something of a hot topic, perhaps because Stephen Hawking commented on the dangers. A science-fiction author I know, David Brin, gets very passionate about this subject because he thinks that we may be threatening the future of humanity. Of course that might be true – we don't know what's out there and it's possible that some fraction of the societies that are out there are aggressive. If they pick up signals that we're here and send their interstellar battlewagons and that's the end of civilisation on Earth, then that's not going to look good on your resumé.

David thinks the SETI community should come out against this, but the SETI community isn't really the problem. We don't have any transmitters and aren't really doing much of this stuff. And are you going to ban transmissions to the sky? The fact is that Heathrow's trying to get in touch every hour of every day thanks to radar. Evidence of our existence here has been going out since the war with the invention of radar – low-frequency AM radio doesn't get through Earth's ionosphere very well, but radar beams are broadcasting into space – and what are you going to do? Are we saying that from now until forever we can't develop any high-frequency transmitters? It's a bit like saying we can't ever build a clever computer because it might be dangerous. The time for worrying about it is long past, and I don't see how it would be a good idea to somehow interdict technological development.

As for the question of who gets to decide what we send – well of course I think I should!

BepiColombo is off to the smallest and innermost planet to answer the questions MESSENGER couldn't

Reported by Lee Cavendish

MISSION TO MERC

Meet the leaders of BepiColombo

Dr Masaki Fujimoto

Fujimoto is Professor of Space Plasma Physics at the Institute of Space and Astronautical Science and JAXA's project scientist for the MMO orbiter, or Mio. He has been involved in many of JAXA's previous space exploration missions, including the Geotail satellite, which studied the Earth's magnetosphere, and the Kaguya orbiter, which was a lunar exploration mission also known as SELENE.

Dr Johannes Benkhoff

Benkhoff is ESA's project scientist for the BepiColombo mission, handling all scientific operations of the MPO, among other aspects. He has also worked on previous ESA missions such as the Rosetta mission, which visited comet 67P/Churyumov–Gerasimenko, and the Venus Express mission – ESA's first spacecraft to journey to Venus to study its atmosphere.

URY

© NASA;

Mercury, the closest planet to the Sun, is an unsolved mystery that has left many questions swirling around the minds of scientists. We have recently been blessed with many missions exploring the outer regions of our Solar System, such as NASA's Juno mission at Jupiter and the New Horizons mission to Pluto and the Kuiper Belt, and the NASA/ESA/ASI Cassini-Huygens mission to Saturn. However, a mission to the inner-most planet poses its own set of challenges and rewards.

Now, the highly anticipated BepiColombo mission, a collaborative mission between the ESA and the Japan Aerospace Exploration Agency (JAXA), will be launched in order to answer the most profound questions about Mercury and our Solar System. Once the BepiColombo stack arrives at Mercury in late 2025 the stack will split apart and send two orbiters into their own unique orbit around the planet. The ESA is responsible for the operation of the Mercury Planetary Orbiter (MPO), and JAXA will operate the Mercury Magnetospheric Orbiter (MMO, or Mio as named by JAXA).

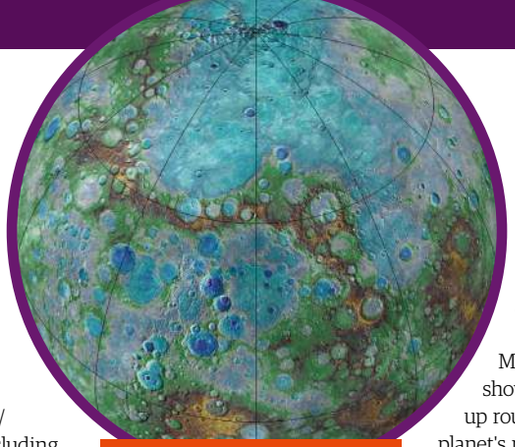
"MPO and MMO complement each other. While the MPO is more focused on studying the planet itself and its interior, the MMO is focused

> "BepiColombo will be perfect to follow up on MESSENGER"
>
> **Dr Johannes Benkhoff**

on studying the plasma, particle and magnetic environment around the planet," explains Benkhoff to **All About Space**. "Therefore the BepiColombo mission will provide a rare opportunity to collect multi-point [on two spacecraft] measurements in a planetary environment."

This ball of metals and silicate materials has a relatively tiny radius of only 2,440 kilometres (1,516 miles), making it smaller than the moons Ganymede and Titan of Jupiter and Saturn respectively. As Mercury sits at an average distance of 58 million kilometres (36 million miles) from the Sun, which is less than 40 per cent of the Sun-Earth distance, this tiny planet exhibits a harsh environment due to its close proximity. The planet faces two different extremes; daytime temperatures can reach a toasty 430 degrees Celsius (806 degrees Fahrenheit) while night-time temperatures, due to Mercury's lack of atmosphere, can drop to a chilly -180 degrees Celsius (-292 degrees Fahrenheit), and the Sun peppers the surface in high-energy particles that have enough power to reach the other planets in the Solar System.

An environment such as this is not an easy one to experience as a spacecraft, let alone sustain a working laboratory for a prolonged time. Only two spacecraft have ever visited the planet. Between 1974 and 1975, NASA's Mariner 10 spacecraft flew by Mercury three times in order to find out about its environment, atmosphere and surface, and it imaged about 45 per cent of its surface.



MESSENGER's revelation of small cliff-like landforms are features that scientists believe are geologically young

Fast-forward to March 2011 and NASA's Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) spacecraft became the first spacecraft to orbit Mercury, making unrivalled observations about every aspect of the planet for about four years and one month. After travelling over 14 billion kilometres (8.7 billion miles) and completing 4,105 orbits of Mercury, and returning over 250,000 images back to Earth in the process, MESSENGER was deliberately crashed into the surface of Mercury on 30 April 2015. The data collected from this mission reshaped our knowledge of Mercury and the evolution of the Solar System, revealing unknown traits about the planet's magnetosphere, surface features and composition.

Although MESSENGER was a pioneering spacecraft, it was still limited by its orbit at the time. "Because of the orbital limitation, there is not enough learned from MESSENGER about the southern hemisphere of the planet" says Fujimoto. "BepiColombo will complete the full-hemisphere coverage and will set the ground to obtain deeper understanding of the issues."

Much like when we look back on any past spacecraft, it was also limited by its technologies of the time, as Benkhoff explains: "BepiColombo, with its comprehensive instrumentation, its sophisticated radio science instrument set, its [thermal and] multi-wavelength spectral imagers, not to mention its much closer orbit allowing full global high-resolution coverage, will be perfect to follow up on MESSENGER."

With a sophisticated instrumental suite of 16 instruments and experiments – five on Mio/MMO and 11 on MPO – including various cameras, spectrometers over a wide range of wavelengths, particle analysers, a magnetometer, a laser altimeter and more, BepiColombo will leave no stone unturned in the examination of Mercury's magnetosphere, exosphere, surface and interior, along with an experiment to test Einstein's theory of general relativity.

The most thought-provoking result that MESSENGER provided was the evidence that Mercury's surface is more abundant in volatile elements such as potassium and sulphur, which completely contradicts the models of Mercury's formation, as well as the entire Solar System. When MESSENGER measured the ratio of potassium (the more volatile element) to thorium (the more stable element), they noticed that abundance of potassium was much higher than thorium. It was previously thought that potassium would have been heated up due to the incredibly high temperatures and evaporated away. However, the copious amounts of potassium show the temperatures were not as high as first thought.

Previous analysis of Mercury's interior also showed that the core makes up roughly 85 per cent of the planet's radius. When compared to Earth's core, which makes up only half of our home planet, it is theorised that Mercury was once a larger planet that had its outer layers cast off in a destructive collision. This is all theory however, and without instruments such as the MPO's Mercury Orbiter Radio-science Experiment (MORE) to further understand the planet's core, and the Spectrometers and Imagers for MPO BepiColombo Integrated Observatory System (SIMBIO-SYS), which will analyse the surface composition, the mystery of Mercury's evolution will remain extremely blurred.

Another important aspect of Mercury that MESSENGER couldn't quite answer is the state of the planet's magnetosphere – the planet's self-driven, magnetic field. Fujimoto says that Mercury shouldn't theoretically exhibit its current intrinsic magnetic field, as there needs to be some sort of liquid or molten interior powering the magnetic activity. A planet as small as Mercury should have cooled down to its core a while ago and cut off its magnetic activity, making its current state a keen area of research.

"Mio is the spacecraft that focuses on this magnetic-oriented science theme. It will observe the magnetic field itself and see how it interacts with the solar wind, the super-sonic flow of ionised gas from the Sun," says Fujimoto. "For this purpose, on board Mio are electromagnetic field instruments, plasma particle detectors and an imaging device for the thin atmosphere that Mercury has."

Observations of Mercury's interior structure, geology and composition are just some of the aspects that BepiColombo will observe. In terms of visually inspecting the rocky surface, MESSENGER was able to locate a source of water ice hidden within the craters at the north pole. With the MPO orbit more comprehensive, the south pole can be scouted for more sources of water ice.

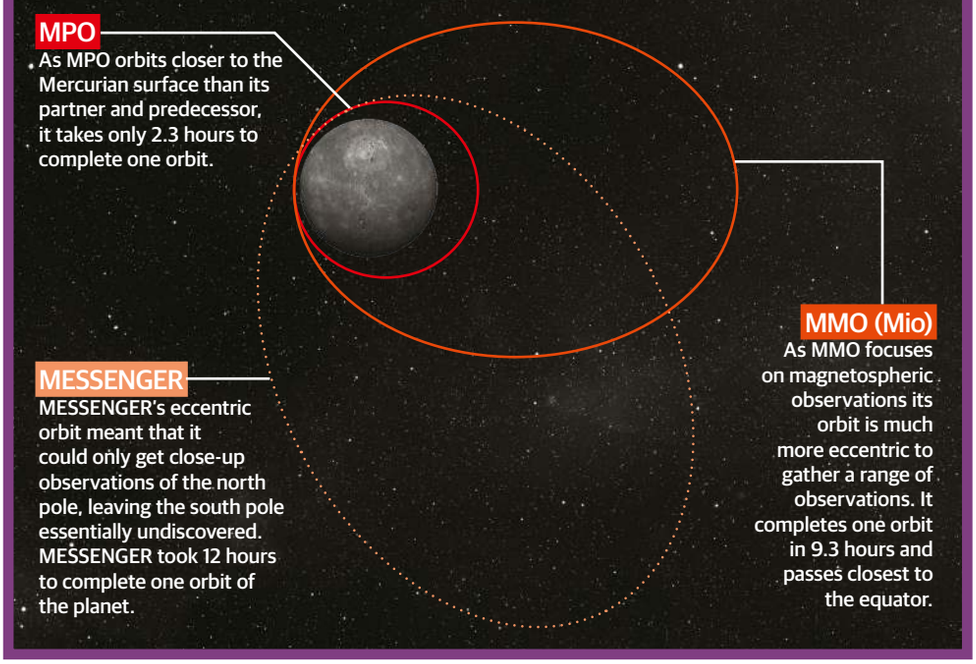
MESSENGER also imaged some interesting surface features called 'hollows' – shallow, irregular depressions on the planet's surface. Along with the observed volcanic features and areas of a young, uncratered land, Mercury's surface could be much more active than originally thought.

The previous MESSENGER mission raised many questions, and even more questions have come along in recent years. With BepiColombo soon to be on its way and scheduled to arrive at Mercury in late 2025, the elusive nature of our most unknown terrestrial planet will be placed under a microscope; this will be another step in understanding the history and formation of Mercury and the inner planets, including Earth. "I strongly believe that the instrumentation of BepiColombo is perfectly suited to obtain our science goals and to deliver answers to the necessary and new questions raised by MESSENGER," concludes Benkhoff.

> "Because of the orbital limitation, there is not enough learned from MESSENGER about the southern hemisphere" **Dr Fujimoto**

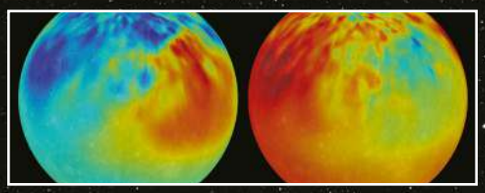
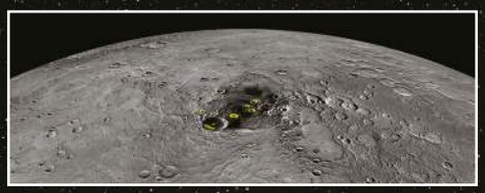
Orbits of Mercury: past and future

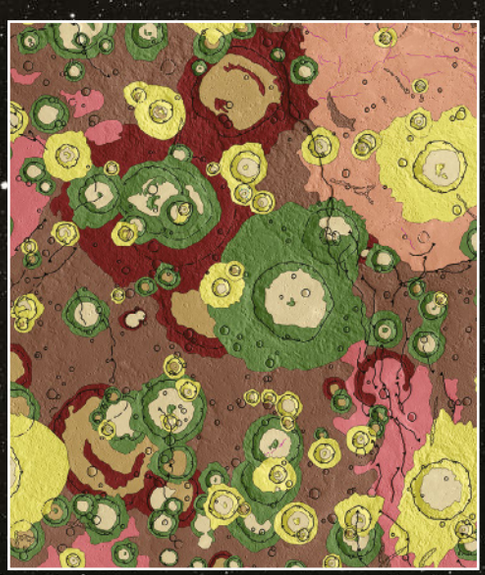
MESSENGER's orbit limited its observations. The two different orbits of the MMO and MPO will offer a more extensive view



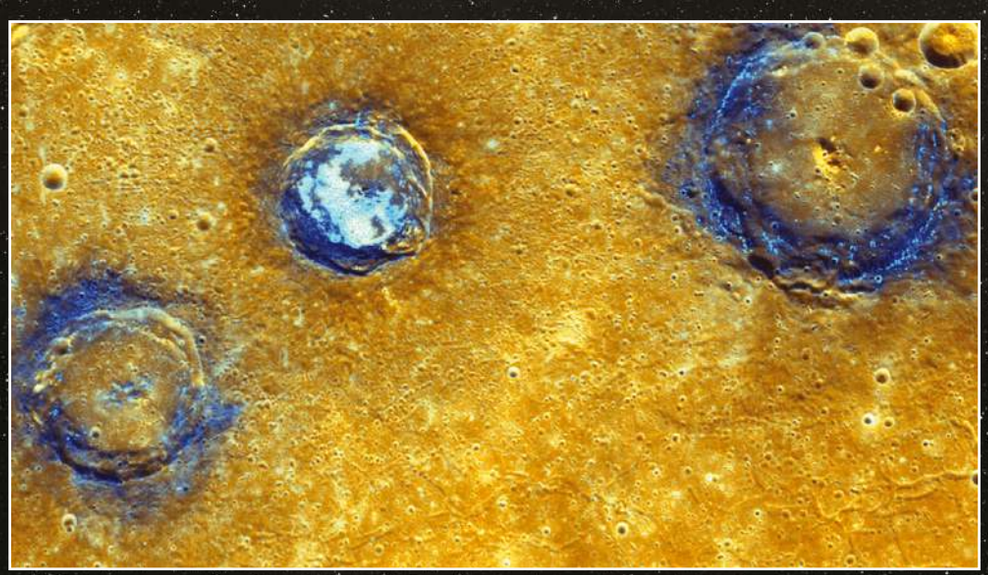
MESSENGER versus BepiColombo

Looking back at MESSENGER's best discoveries and what to look forward to with BepiColombo

MESSENGER	RESULTS	BEPICOLOMBO
A volatile start for Mercury After analysing the potassium to thorium ratio of the planet, scientists determined that Mercury is more abundant in volatile elements. This contradicts previous planetary formation models of Mercury and the Solar System.		**Detailed spectroscopy** With an inventive array of improved spectrometers BepiColombo will be able to analyse different elements around the planet, gaining a clearer insight into the planet's composition. This also includes the southern hemisphere that wasn't fully covered before.
Ice at the north pole MESSENGER supplied vital evidence for the presence of water ice (shown in yellow) hidden in the shadows of craters peppered at the north pole of Mercury, courtesy of its Mercury Dual Imaging System instrument.		**Looking to the south** BepiColombo's Probing of Hermean Exosphere by Ultraviolet Spectroscopy (PHEBUS) instrument will be able to further analyse high-latitude craters in the search for water ice, as well as looking for it at the south pole.
The mad magnetic field MESSENGER revealed that the planet's magnetic field is offset by 20 per cent from the planet's radius. The magnetic field is 100-times weaker than Earth's and can barely withhold the advances of the solar wind. MESSENGER was able to get the full picture.		**Specially designed magnometer** The MMO is primarily dedicated to Mercury's magnetosphere and has instruments like the Mercury Magnetometer (MMO-MAG) to investigate further and determine the interactions between the solar wind and Mercury's magnetic field.
Holey hollows MESSENGER's images revealed unusually shallow depressions in the surface of Mercury known as 'hollows'. How these features transpire is still ongoing, and they are thought to be escape of material through sublimation.		**Highlighting the hollows** With a number of imagers, most specifically the SIMBIO-SYS instrument, the surface will be imaged in high-resolution colour and stereo. This will show hollows in more detail. Spectrometers will analyse their composition, looking for any clues about their evolution.
Young surface with volcanic deposits Mercury flaunts a surprisingly young surface with what appear to be volcanic deposits relaying the cratered surface in order to create a much smoother one. These volcanic deposits were imaged by MESSENGER and showed clear paths made from lava flows.		**Probing deeper** The analysis of the planet's interior will reveal more of the molten or liquid presence within the planet, revealing more about the volcanic activity dispersing this molten material paving the surface, along with further compositional analysis to see what it is made of.



Map showing the geology of the Victoria Quadrangle

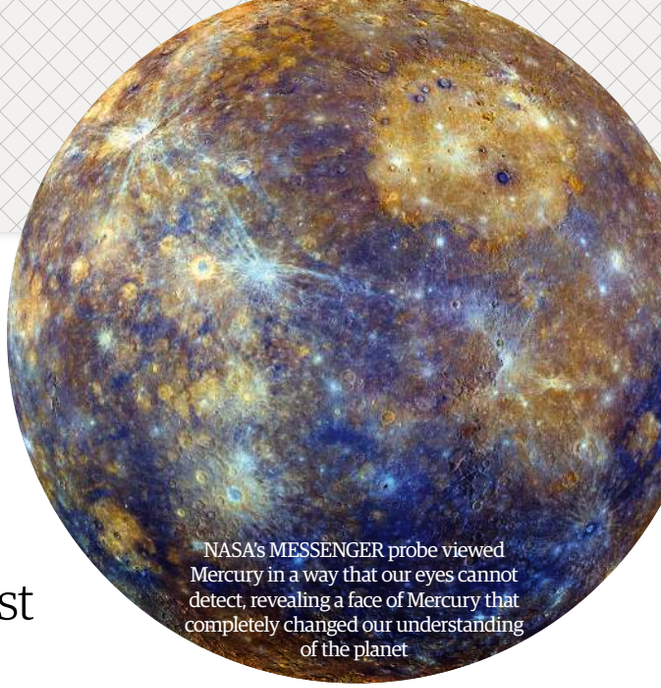


MESSENGER's colour-enhanced mosaic show smooth volcanic plains, craters and hollows

USER MANUAL

BepiColombo

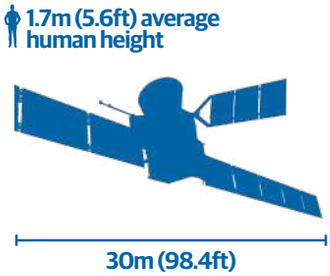
A collaborative effort between ESA and JAXA, the spacecraft will provide the best understanding of Mercury to date



NASA's MESSENGER probe viewed Mercury in a way that our eyes cannot detect, revealing a face of Mercury that completely changed our understanding of the planet

THE SPECS

Launch: 19 October 2018 (UTC)
Rocket: Ariane 5
Target: Mercury
Operator: ESA and JAXA
Estimated cost: £1.5 billion ($2 billion)
Time in space: One Earth year (possible one Earth year extension)
Distance from Earth: At least 77 million kilometres (48 million miles)



Scheduled to launch on 19 October 2018, BepiColombo will be a first-of-its-kind mission for both the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA). This mission will explore Mercury – the least explored terrestial planet in our Solar System. Only two spacecraft have ever paid the tiny planet a visit: NASA's Mariner 10 and MESSENGER probes.

The BepiColombo mission is named after Professor Giuseppe (Bepi) Colombo (1920-1984), a mathematician and engineer at the University of Padua, Italy, who was the first person to see that there was an unusual resonance between Mercury's three rotations to every two orbits of the Sun. His namesake will be launched from Europe's spaceport in Kourou, French Guiana, aboard an Ariane 5 rocket. The four-part BepiColombo spacecraft 'stack' will travel for over seven years through the inner Solar System before it arrives at Mercury after a series of flybys of Earth, Venus and Mercury.

This four-part spacecraft includes the Mercury Transfer Module (MTM), which will transport the two orbiters safe and sound to their intended destination. The MTM can be thought of as the bottom of the stack. On top of the MTM sits one of the orbiters, the Mercury Planetary Orbiter (MPO), led by the ESA, which includes 11 instruments that will probe every aspect of Mercury. The Mercury Magnetospheric Orbiter (MMO), led by JAXA, will sit at the tip of the BepiColombo stack, and has a further five instruments in order to do a bit more probing. It will be protected by the MMO Sunshield and Interface Structure (MOSIF) during the journey, but MOSIF will be jettisoned upon the spacecraft's planned arrival at Mercury in December 2025.

Although Mariner 10 and MESSENGER learnt a lot about the surface of Mercury and its unusual magnetic field, there is so much more still to be discovered. This is why ESA and JAXA put their heads together to birth this mission that will put two separate orbiters around Mercury in a journey never undertaken by either space agency before.

The journey to the innermost planet is a difficult one, as the huge gravity of the Sun becomes more and more intense on the spacecraft at it makes the 77-million-kilometre (48-million-mile) approach towards the centre of our Solar System. On its approach to Mercury the spacecraft will inevitably accelerate as the Sun's gravity pulls it in. This is a challenge that neither ESA or JAXA have encountered before, as they usually send spacecraft in the opposite direction, away from the Sun. To

BepiColombo will complete one flyby of Earth in April 2020 and a further two flybys at Venus and six at Mercury

Anatomy of BepiColombo

This incredibly large suite of instruments will probe every aspect of Mercury from top to bottom to uncover the secrets of this mysterious planet

KEY

BELA – BepiColombo Laser Altimeter

ISA – Italian Spring Accelerometer

MDM – Mercury Dust Monitor

MERTIS – Mercury Radiometer and Thermal Imaging Spectrometer

MGNS – Mercury Gamma-ray and Neutron Spectrometer

MIXS – Mercury Imaging X-ray Spectrometer

MMO-MAG – Mercury Magnetometer

MORE – Mercury Orbiter Radio science Experiment

MPO-MAG – Magnetic Field Investigation

MPPE – Mercury Plasma Particle Experiment

MSASI – Mercury Sodium Atmosphere Spectral Imager

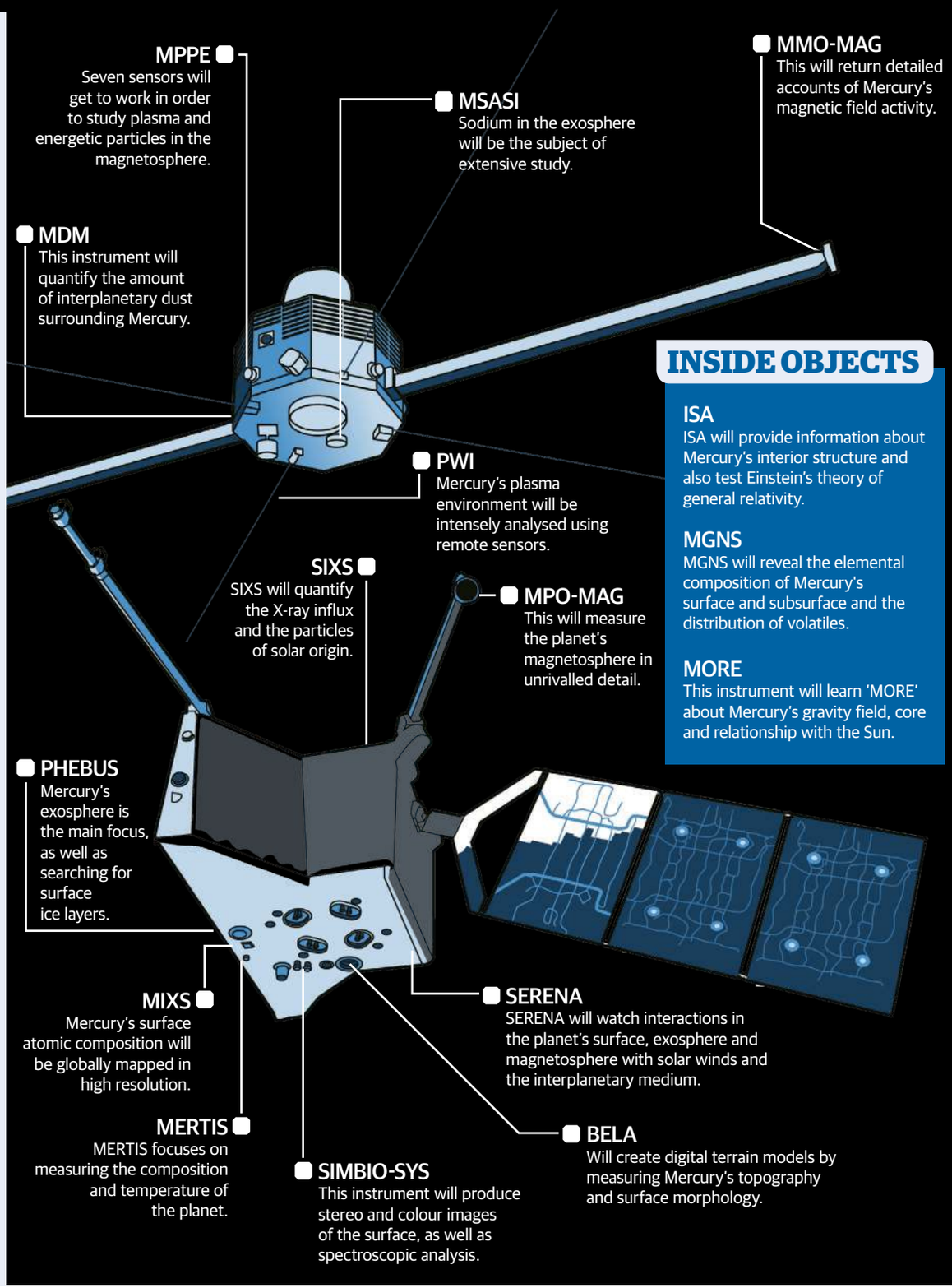
PHEBUS – Probing of Hermean Exosphere by Ultraviolet Spectroscopy

PWI – Mercury Plasma Wave Instrument

SERENA – Search for Exosphere Refilling and Emitted Neutral Abundances

SIMBIO-SYS – Spectrometers and Imagers for MPO BepiColombo Integrated Observatory

SIXS – Solar Intensity X-ray and particle Spectrometer



MPPE
Seven sensors will get to work in order to study plasma and energetic particles in the magnetosphere.

MSASI
Sodium in the exosphere will be the subject of extensive study.

MMO-MAG
This will return detailed accounts of Mercury's magnetic field activity.

MDM
This instrument will quantify the amount of interplanetary dust surrounding Mercury.

PWI
Mercury's plasma environment will be intensely analysed using remote sensors.

SIXS
SIXS will quantify the X-ray influx and the particles of solar origin.

MPO-MAG
This will measure the planet's magnetosphere in unrivalled detail.

PHEBUS
Mercury's exosphere is the main focus, as well as searching for surface ice layers.

MIXS
Mercury's surface atomic composition will be globally mapped in high resolution.

MERTIS
MERTIS focuses on measuring the composition and temperature of the planet.

SIMBIO-SYS
This instrument will produce stereo and colour images of the surface, as well as spectroscopic analysis.

SERENA
SERENA will watch interactions in the planet's surface, exosphere and magnetosphere with solar winds and the interplanetary medium.

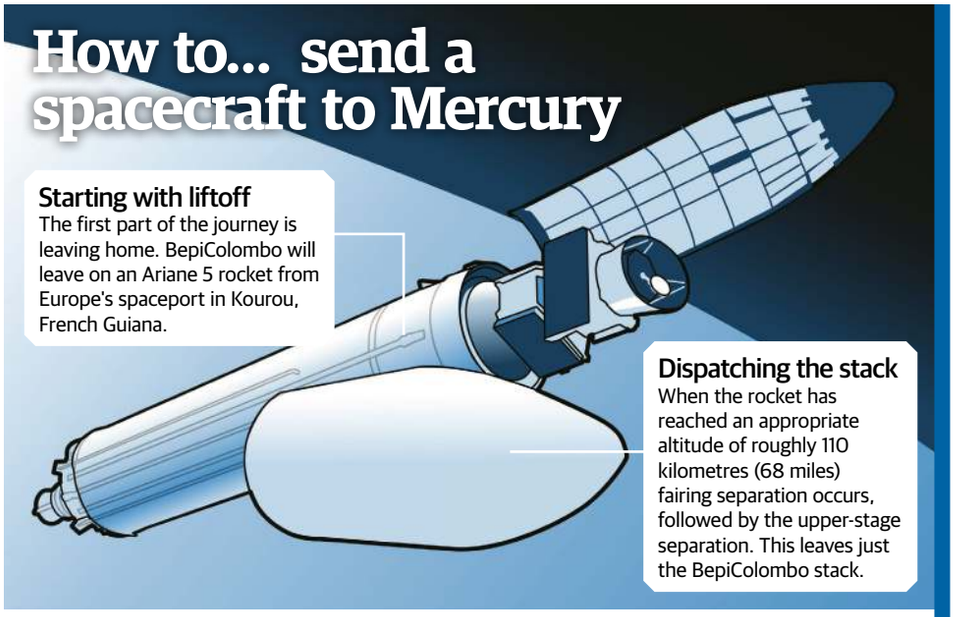
BELA
Will create digital terrain models by measuring Mercury's topography and surface morphology.

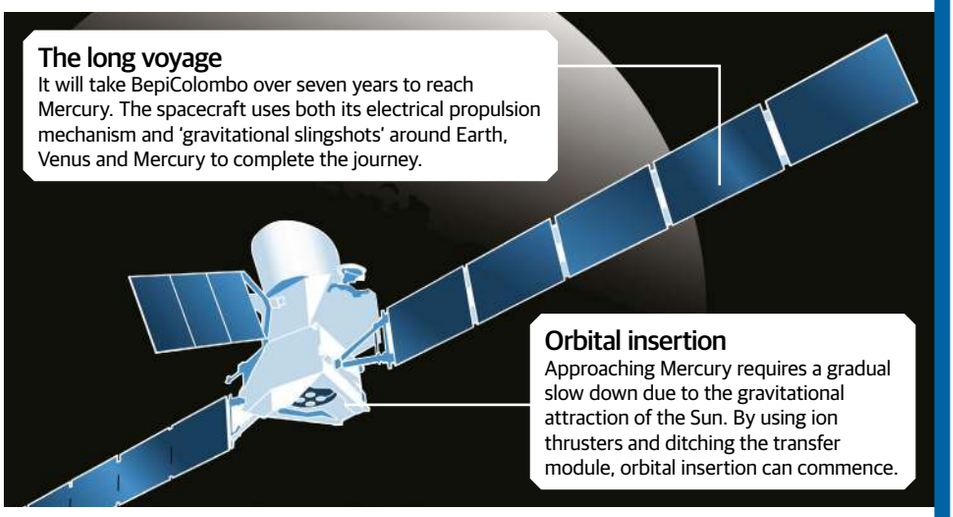
INSIDE OBJECTS

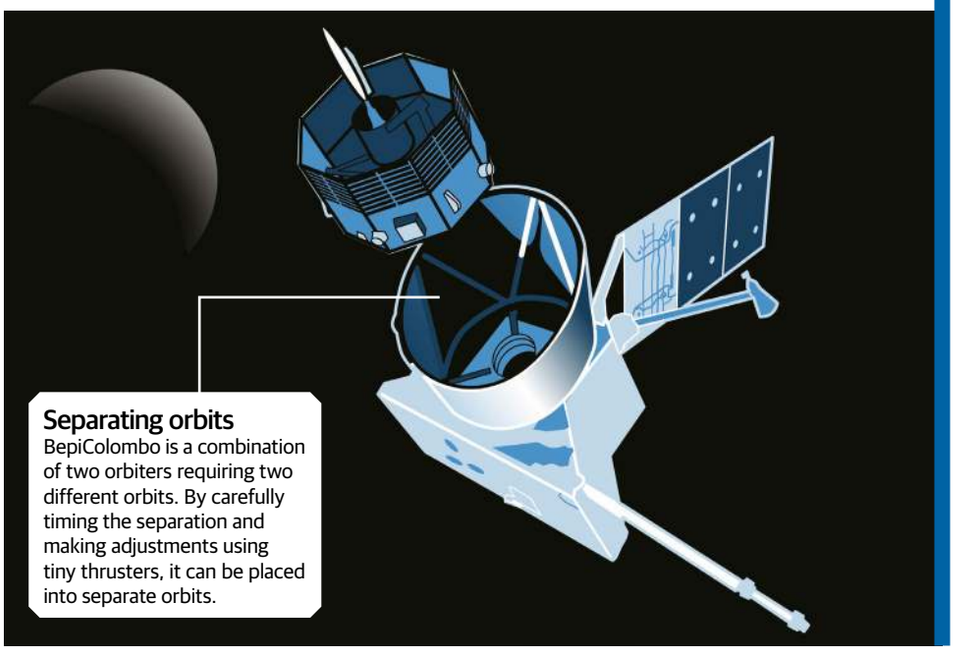
ISA
ISA will provide information about Mercury's interior structure and also test Einstein's theory of general relativity.

MGNS
MGNS will reveal the elemental composition of Mercury's surface and subsurface and the distribution of volatiles.

MORE
This instrument will learn 'MORE' about Mercury's gravity field, core and relationship with the Sun.







Engineers have worked laboriously at Europe's Spaceport ahead of its launch in October 2018, including making sure the MMO is finely tuned and ready for the harsh journey ahead

slow down the spacecraft upon arrival at Mercury, six Mercury flybys and ion thrusters will allow the spacecraft to be captured, placing the orbiters into their intended orbits.

On 5 December 2025, BepiColombo is due to finally arrive at Mercury and can begin the highly anticipated mission that will reveal previously unknown details about the planet's composition, geophysics, atmosphere, magnetosphere and its evolution. The mission has been scheduled for one Earth year (about four Mercurian years), with the possibility of another Earth year extension. Before this mission begins, the two orbiters must be carefully placed into their different orbits, which requires a fine level of precision.

Upon arrival the MTM is separated from the stack, sending the other three sections onward. The first orbiter to be released will be the MMO, which is an octagonal prism with a diameter of 1.8 metres (5.9 foot) and 1.1 metres (3.6 foot) in height and has a mass of 255 kilograms (562 pounds). It will be placed into a polar orbit, taking 9.3 hours per orbit. Due to the elliptical nature of this orbit, the spacecraft can come as close as 590 kilometres (367 miles) of the planet's surface, or as far as 11,640 kilometres (7,233 miles). While making its way around Mercury MMO will continuously spin, completing 15 rotations per minute. The spin axis will make sure that the top and bottom of the spacecraft (where the instruments show) will never be pointed at the Sun, while simultaneously making sure the orbiter's antennae are pointed towards Earth for constant communication.

Next to be jettisoned is the sunshield after its job has been completed in keeping the MMO safe on its travels. The final module is the MPO, which measures 2.2 metres (7.2 foot) wide, 2.4 metres (7.9 foot) long and 1.7 metres (5.6 foot) tall, and a rough mass of 1,230 kilograms (2,712 pounds). This orbiter is placed in a much closer orbit, flying between 480 and 1,500 kilometres (298 and 932 miles) of the surface and completing one orbit every 2.3 hours.

The MPO incorporates a different design to the MMO, as it will sit closer to Mercury. Mercury radiates copious amounts of heat due to its close proximity to the Sun and reflective surface, which means that scientists and engineers had to design MPO so that the planet's - and the Sun's - heat isn't a problem. To do so, engineers constructed MPO in a double-H configuration that contains a large radiator with connecting pipes so that it can collect the heat and dispose of it efficiently.

TOP TECH

Mercury Planetary Orbiter (MPO): ESA's instrumental steward

It's hard to pin down one specific instrument from the 16 that constitute BepiColombo, as each instrument is as important as the next. However, the ESA's MPO orbiter holds 11 instruments that can unlock the secrets of Mercury's elusive surface and composition.

With imagers, spectrographs and other high-tech equipment, the MPO will undoubtedly show scientists Mercury's past and its evolution into its current state, from the core to the magnetosphere. By using instruments that are tuned to look at Mercury in wavelengths unperceivable to the human eye, the nature of Mercury will be explored after BepiColombo's arrival.

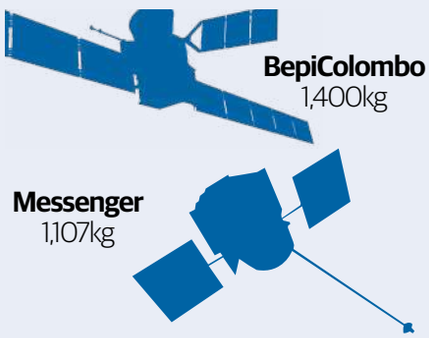
Head-to-head

BepiColombo vs Messenger

The Mercury Surface, Space Environment, Geochemistry, and Ranging, or MESSENGER, became the first spacecraft to orbit Mercury on 18 March 2011 (UTC). BepiColombo will be the second-ever mission to orbit Mercury.

In terms of size, MESSENGER was smaller than BepiColombo's MPO (the larger of the two orbiters). MESSENGER's main body was 1.44 metres (4.7 foot) high, 1.28 metres (4.2 foot) long and 1.85 metres (6.1 foot) wide. MPO is 0.26 metres (0.9 foot) taller, 1.12 metres (3.7 foot) longer and 0.35 metres (0.8 foot) wider.

The BepiColombo orbiters have over two-times as many instruments as MESSENGER. This means the observational firepower at ESA and JAXA's disposal is something never to have graced Mercury before.



Vital statistics

10 years = The time since NASA's MESSENGER arrived at Mercury

430 degrees Celsius = The day side surface temperature on Mercury

7.2 years = The length of BepiColombo's journey to Mercury

4,100 kilograms = The total mass of the four-spacecraft BepiColombo stack at launch

16 = The total number of instruments that will explore Mercury

HOW TO...

Survive the Sun's heat

1 Hand-stitching insulation

Engineers have taken many aspects into consideration to ensure BepiColombo's safety. This includes incorporating hand-stitched, multi-layer insulation, temperature-resistant materials and reflective coatings.

2 MMO Sunshield and Interface Structure

The MMO requires a special sunshield. The MMO will be able to handle the Sun's radiation once it is in a spin-stabilised orbit at Mercury, however, MMO needs MOSIF to protect it until then.

3 Mercury Planetary Orbiter

MPO is the larger of the two orbiters, with more surface area for heat to be taken in. To prevent a heat build-up in the orbiter engineers have fitted a main radiator and pipes throughout the system so that heat can be removed.

4 Mercury Magnetospheric Orbiter

The MMO doesn't have a radiator and heat pipes like the MPO. The constant spinning of the orbiter means that each of its eight sides have an equal exposure to sunlight. Each of the eight sides are equipped with solar panels.

MEET NASA'S NEW COMMERCIAL CREW

The first-ever selection of astronauts that will test the exploration capabilities of SpaceX and Boeing has now been announced

On Friday 3 August 2018 a huge step was made in incorporating privately funded organisations into government-led space exploration missions. NASA announced the first-ever 'Commercial Crew' that will test both Boeing's CST-100 Starliner and SpaceX's Crew Dragon missions. These commercial spacecraft will take astronauts to and from low-Earth orbit and the International Space Station (ISS).

"Today, our country's dreams of greater achievements in space are within our grasp," NASA administrator Jim Bridenstine said on the day of the announcement. "This accomplished group of American astronauts, flying on new spacecraft developed by our commercial partners Boeing and SpaceX, will launch a new era of human spaceflight. Today's announcement advances our great American vision and strengthens the nation's leadership in space."

NASA has worked closely with these companies in the past, having had much cooperation with Elon Musk's SpaceX in resupply missions to the ISS. Although there hasn't been the same level in teamwork with Boeing, all companies have worked closely together to ensure that any design reaches the high standards of NASA.

Nine astronauts have been selected for four missions, with two and three astronauts on the Crew Dragon test flight and the Starliner test flight missions respectively, and a further two astronauts a piece on the first actual missions of the commercial spacecraft. All of these astronauts are held in very high esteem, and all but two have experienced spaceflight previously.

After the five astronauts have successfully undergone test flights for the two spacecraft, NASA can give its stamp of approval and allow the spacecraft and systems on further missions to the Space Station. NASA has awarded contracts for six missions to each of the companies, and they also delegated four astronauts per mission. After this, NASA will announce any additional astronauts after liaisons with their international partners in the name of consistent international collaboration.

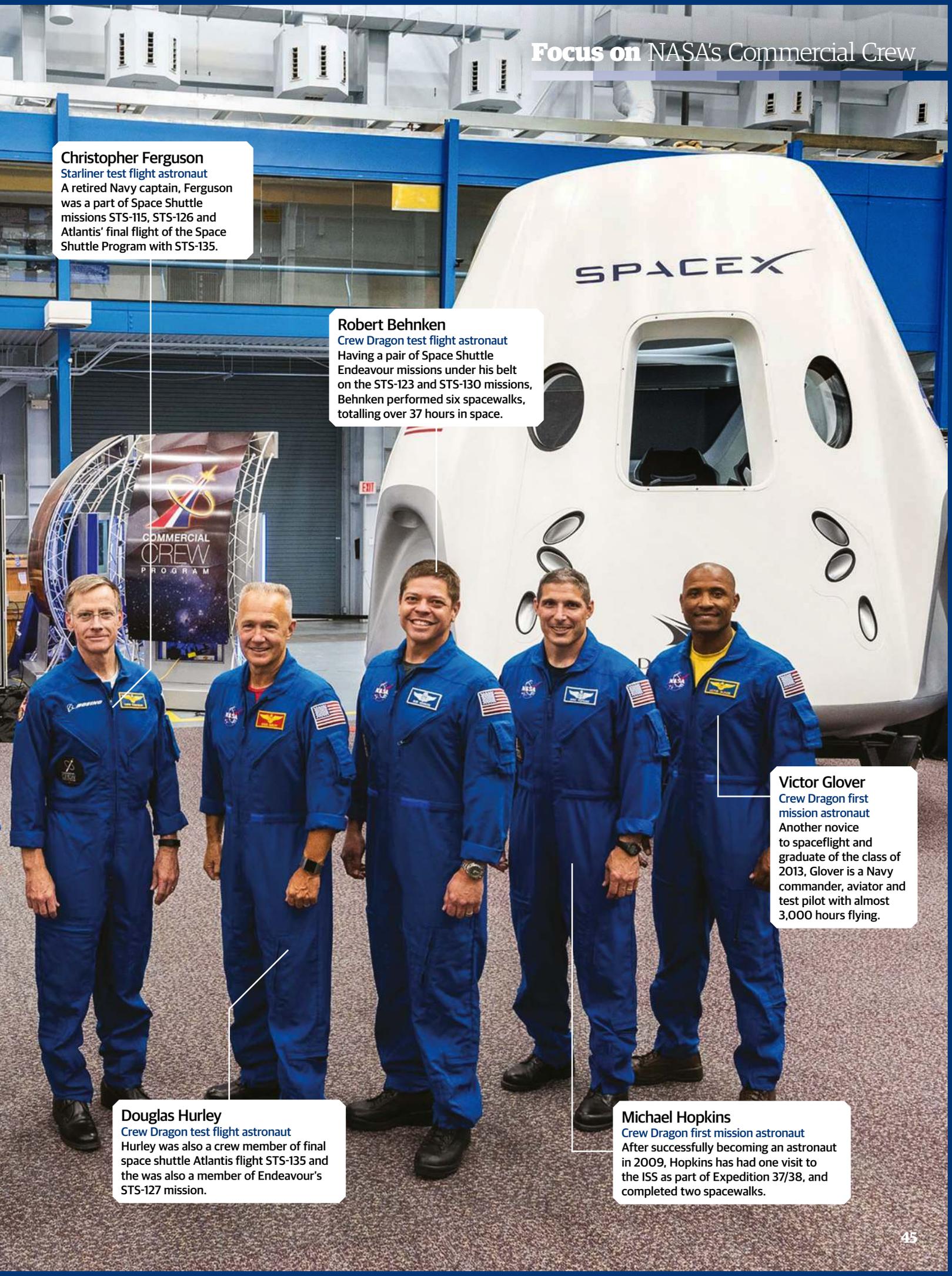
"The men and women we assign to these first flights are at the forefront of this exciting new time for human spaceflight," says Mark Geyer, director of NASA's Johnson Space Center in Houston, Texas, United States. "It will be thrilling to see our astronauts lift off from American soil, and we can't wait to see them aboard the ISS."

Eric Boe
Starliner test flight astronaut
Since being selected as an astronaut in 2000, piloted the Space Shuttle Endeavour for STS-126 and Discovery's final flight as part of STS-133.

Sunita Williams
Starliner first mission astronaut
Previous experience includes spending a total of 222 days aboard the ISS for Expeditions 14/15 and 32/33, commanding it in the process.

Josh Cassada
Starliner first mission astronaut
This will be his first flight, having been selected for astronaut duty in 2013 after more than 3,500 flight hours as a test pilot and Navy commander.

Nicole Aunapu Mann
Starliner test flight astronaut
Mann was selected as an astronaut comparatively recently in 2013, and also holds the title of lieutenant colonel in the Marine Corps.



Christopher Ferguson
Starliner test flight astronaut
A retired Navy captain, Ferguson was a part of Space Shuttle missions STS-115, STS-126 and Atlantis' final flight of the Space Shuttle Program with STS-135.

Robert Behnken
Crew Dragon test flight astronaut
Having a pair of Space Shuttle Endeavour missions under his belt on the STS-123 and STS-130 missions, Behnken performed six spacewalks, totalling over 37 hours in space.

Victor Glover
Crew Dragon first mission astronaut
Another novice to spaceflight and graduate of the class of 2013, Glover is a Navy commander, aviator and test pilot with almost 3,000 hours flying.

Douglas Hurley
Crew Dragon test flight astronaut
Hurley was also a crew member of final space shuttle Atlantis flight STS-135 and the was also a member of Endeavour's STS-127 mission.

Michael Hopkins
Crew Dragon first mission astronaut
After successfully becoming an astronaut in 2009, Hopkins has had one visit to the ISS as part of Expedition 37/38, and completed two spacewalks.

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ASTROPHYSICS

Can light escape black holes?

Yes and no. Black holes were first unambiguously identified in our galaxy more than 40 years ago, and since then they have been found in vast numbers both in the Milky Way and also at the cores of pretty much every large galaxy that has been studied in detail. The holy grail of observational research in this field is to obtain an 'image' of the immediate surroundings of a black hole and to observe the flows of matter around it. All of our theory tells us that nothing can escape from the event horizon of a black hole, not even light. In fact, this is how a black hole is characterised. However, theory also tells us that indirect exchange of energy can make the event horizons glow in a process first proposed by physicist Stephen Hawking. Finding evidence of such glowing black hole horizons will be a very important discovery, but none have been found so far.

As our telescopes become more powerful across the full spectrum of energies, from radio waves to gamma rays, we aim to probe ever closer to black holes in the universe. Who knows what surprises we may find.

Poshak Gandhi, associate professor in the School of Physics and Astronomy at the University of Southampton

Imaging a black hole would be a huge scientific breakthrough

HUNT FOR LIFE

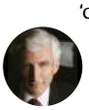
How would we recognise other life in the universe?

Even if primitive life and vegetation were ubiquitous, 'advanced' life may not be, because our emergence on Earth may have depended on many contingencies, such as the phases of glaciation, the planet's tectonic history, the presence of the Moon and so forth. But SETI searches are surely worthwhile.

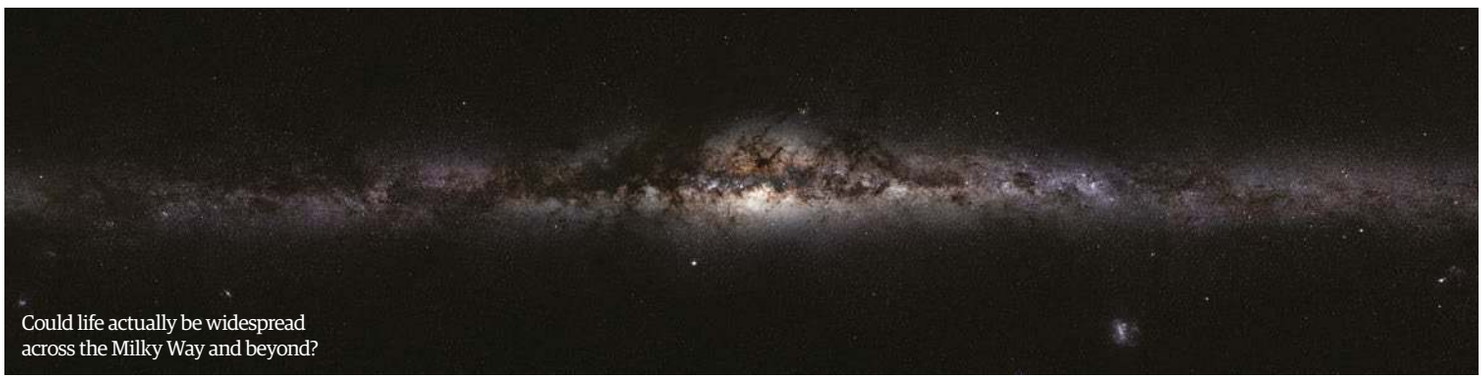
Instruments are searching for non-natural radio transmissions from nearby and distant stars, from the plane of the Milky Way, from the Galactic Centre and from nearby galaxies. But, even if the search succeeded, it would still be unlikely that the 'signal' would be a decodable message.

A radio engineer familiar only with amplitude-modulation might have a hard time decoding modern wireless communications. Indeed, compression techniques aim to make the signal as close to noise as possible – insofar as a signal is predictable, there's scope for more compression. And the signal could just be 'leakage' anyway, rather than any kind of message.

Then again, many of us think that 'organic' human-level intelligence is just a brief interlude before the machines take over – before 'organics' are overtaken or transcended by inorganic intelligence which will then persist, continuing to evolve for billions of years. This suggests that if we were to detect ET, it would be far more likely to be inorganic: we would be most unlikely to 'catch' alien intelligence in the brief sliver of time when it was still in organic form.

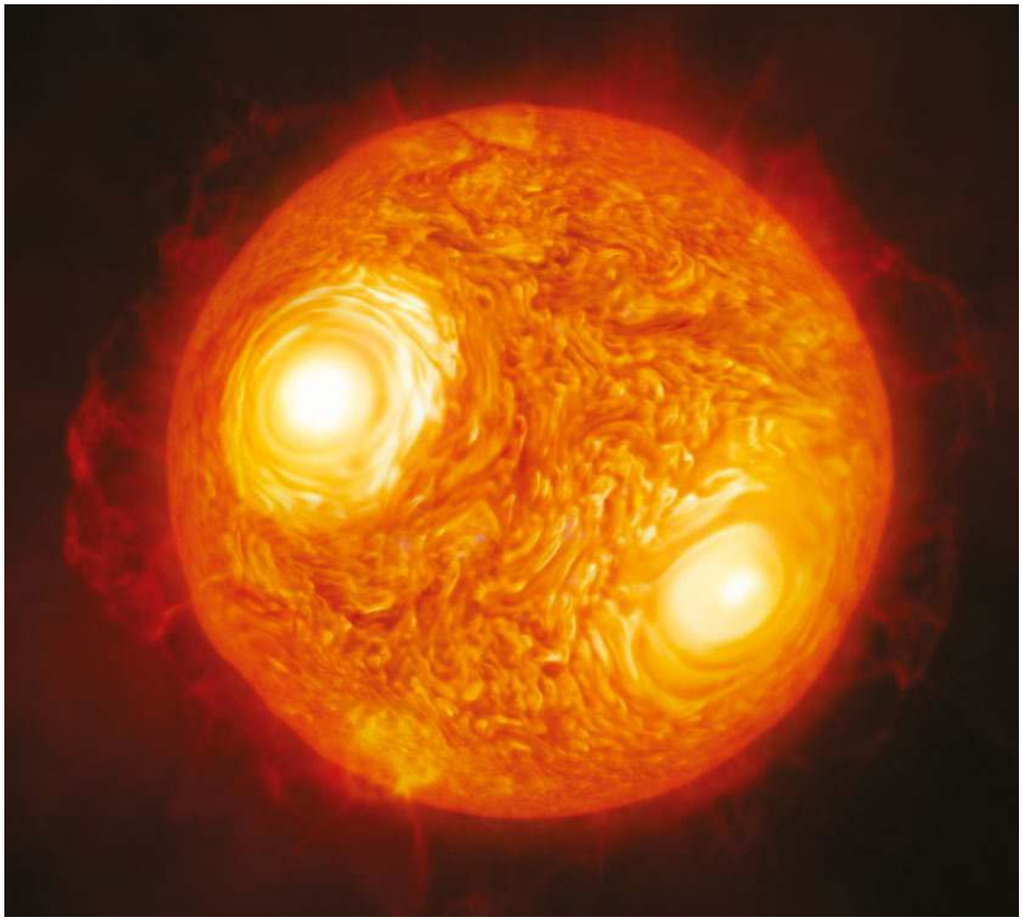


Martin Rees, British cosmologist and astrophysicist who has been Astronomer Royal since 1995



Could life actually be widespread across the Milky Way and beyond?

Make contact: @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com



The size of a star depends on how much material it absorbed from dust clouds and gases in space

ASTROPHYSICS

Why do stars have different masses?

Stars have different masses because they are born that way, unlike humans who continue to gain weight throughout their lifetimes. The difference lies in the fact that stars gain all their mass at birth when they accrete nearby material in their gravitational influence until there is no more material left, whereas humans 'accrete' food whenever their appetite says so!

Stars generally have masses between one tenth and a few hundred-times the mass of the Sun. At the low end, stars with insufficient mass do not burn hydrogen because there is not enough mass to compress the material in their cores to high enough pressures. At the high end, it is not clear what limits the masses of stars. Some astronomers claim that there is an upper limit of around 150-times the mass of the Sun, although other astronomers believe that there is no limit, or that the limit is higher.

Donald Figer, astronomer at the Rochester Institute of Technology and director of the Future Photon Initiative and the Center for Detectors

SPACE EXPLORATION

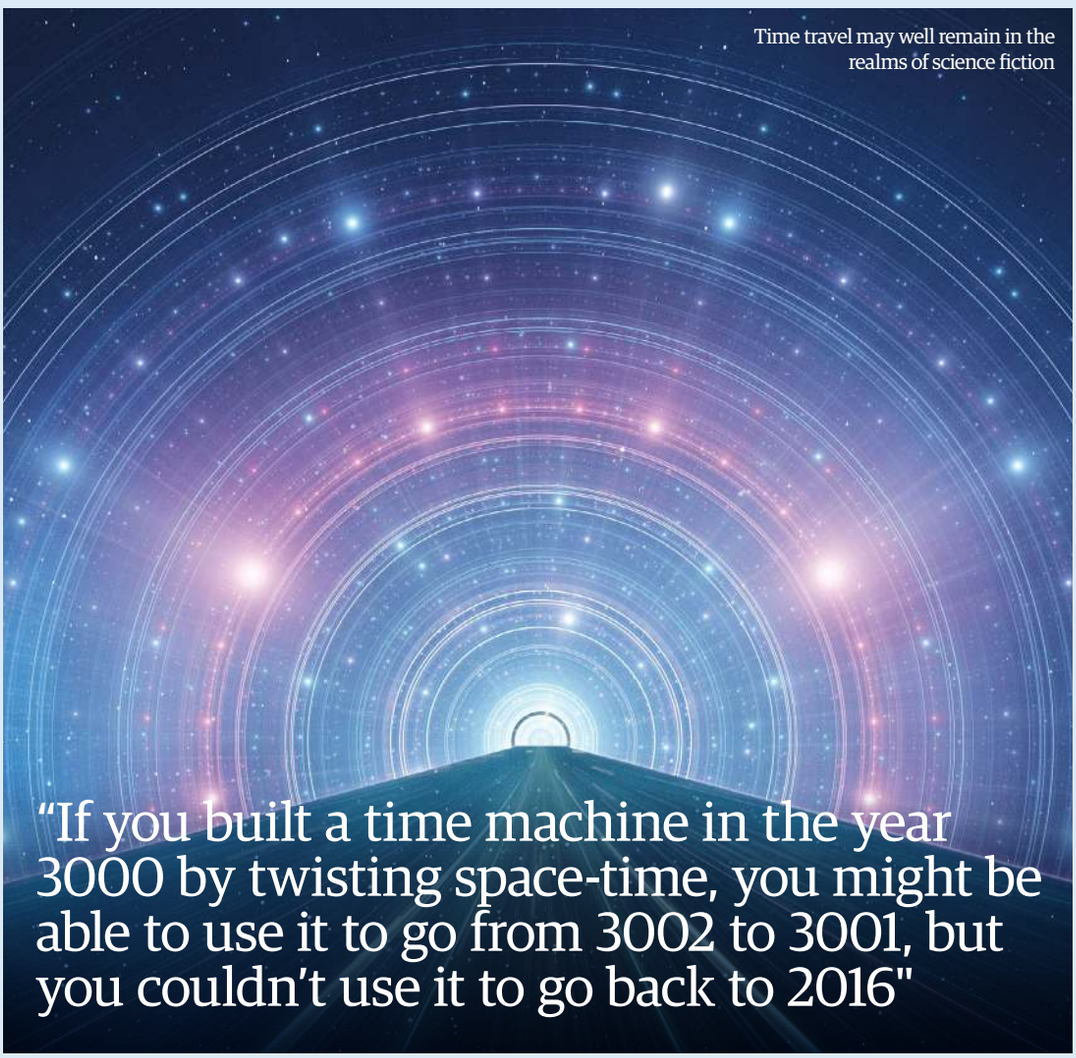
Will we ever be able to travel backwards in time?

Einstein's theory of general relativity – our best theory of gravity, which has passed every experimental test so far – has some solutions that are sufficiently twisted so as to allow time travel to the past. These include wormholes and moving cosmic strings. Just as Magellan's crew went west, west, west around the world and arrived back in Europe, a time traveller can go steadily toward the future and yet circle back through curved space-time to visit an event in their own past.

If you built a time machine in the year 3000 by twisting space-time, you might be able to use it to go from 3002 to 3001, but you couldn't use it to go back to 2016 because that was before the time machine was built. It would take a supercivilisation to even attempt such a project.

To know whether these time machines could be created in practice, we may need to learn the laws of quantum gravity, or how gravity behaves on microscopic scales. It's one of the reasons physicists find the possibilities of time travel so interesting.

J. Richard Gott, professor of astrophysical sciences at Princeton University



Time travel may well remain in the realms of science fiction

We are currently aware of almost 4,000 exoplanets' existence

"We are now certain that potentially habitable planets do exist around other stars, but they remain difficult to detect"

HUNT FOR LIFE

How common are planets that can support advanced technology like ours?

There is as yet no scientifically rigorous answer to this question. The Drake equation is one theoretical model for how common planets are with intelligent life. NASA is also working towards answering parts of this question: Scientists are studying the fraction of stars that have planets where water can exist as a liquid on the surface, and the fraction of those planets that have Earth-like atmospheres. Only partial answers are available to these questions at this time. We are now certain that potentially habitable planets do exist around other stars, but they remain difficult to detect. Even for the nearest stars, we are not yet capable of detecting the habitable planets that may exist around them. And we still lack information as to whether they have Earth-like atmospheres. We are laying big plans to answer these questions by direct observations with future space telescopes – two such possibilities are HabEx and LUVOIR.

Karl Stapelfeldt is chief scientist of the NASA Exoplanet Exploration Program

ASTROPHYSICS

How hot is dark matter?

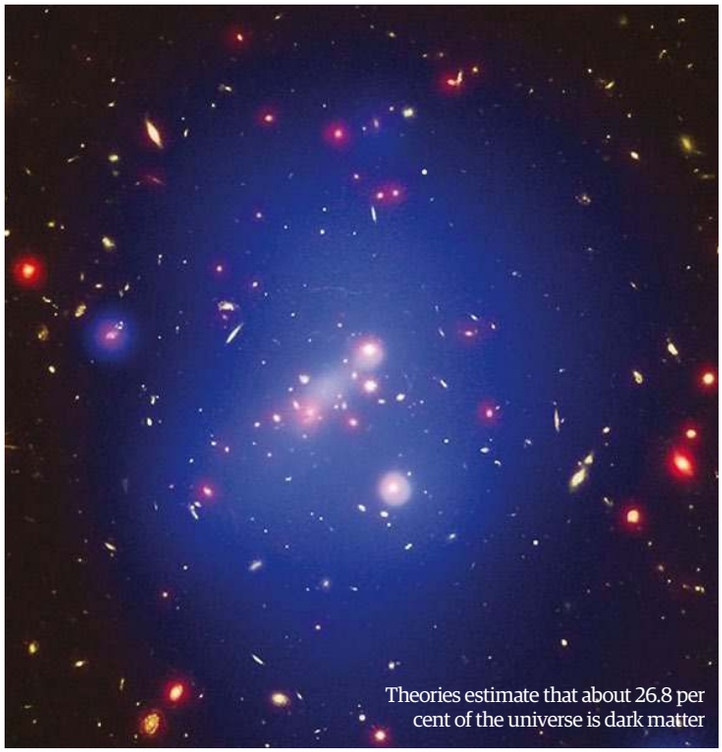
Competing theories suggest that dark matter may be cold, warm or hot. The temperature refers to particles' speed. Cold dark matter particles sit still, like water molecules frozen in ice; hot dark matter particles zip about like molecules in steam, spreading into their surroundings.

The speed of dark matter particles mattered when they emerged from the Big Bang. Set loose in computer simulations, cold dark matter particles don't move. Gravity pulls them together, creating lumps in the primordial soup. Hot dark matter particles whiz around near the speed of light, stirring it up.

Fortunately for us, most real dark matter was tepid. It created lumps that eventually grew into habitable galaxies like the Milky Way. Confusingly, the theories' names have nothing to do with the present speed of dark matter particles. Our universe expanded so rapidly that the initial motion of any dark matter particles became irrelevant. Then particles fell into galaxies, picking up speed. Dark matter particles in the Milky Way now move 20 kilometres (12.4 miles) every second. That's twice as fast as hydrogen on the surface of the Sun.

Underground particle detectors are looking for cold dark matter particles known as WIMPs, but controversial evidence has recently emerged for sterile neutrinos, a type of warm dark matter. A satellite to map this warm dark matter was lost in March, keeping the debate open for now.

Richard Massey is a physicist working as a Royal Society research fellow in the Institute for Computational Cosmology at Durham University



Theories estimate that about 26.8 per cent of the universe is dark matter

Questions to... @spaceanswers /AllAboutSpaceMagazine space@spaceanswers.com

The Great Red Spot has been observed continuously since 1830

THE PLANETS

What is causing Jupiter's Great Red Spot?

Jupiter is a gaseous/fluid planet with rapid rotation, which causes the winds to organise into bands of easterlies and westerlies, but also causes turbulence. Vortices (cyclones and anticyclones) are a natural feature of this kind of turbulent air flow. The Great Red Spot is an anticyclone, spinning in the counterclockwise direction in Jupiter's southern hemisphere.

It is more stable than an anticyclone would be on Earth because there are fewer disruptions, like land masses, to cause it to break apart. It is also confined by strong winds to not move in latitude, unlike a terrestrial hurricane or cyclone, making it even more stable. In essence it is a storm rolling like a ball bearing in a moving channel of winds.

Amy Simon is a senior scientist specialising in planetary atmosphere for NASA

Saturn's rings consist of mostly ice, rock and dust

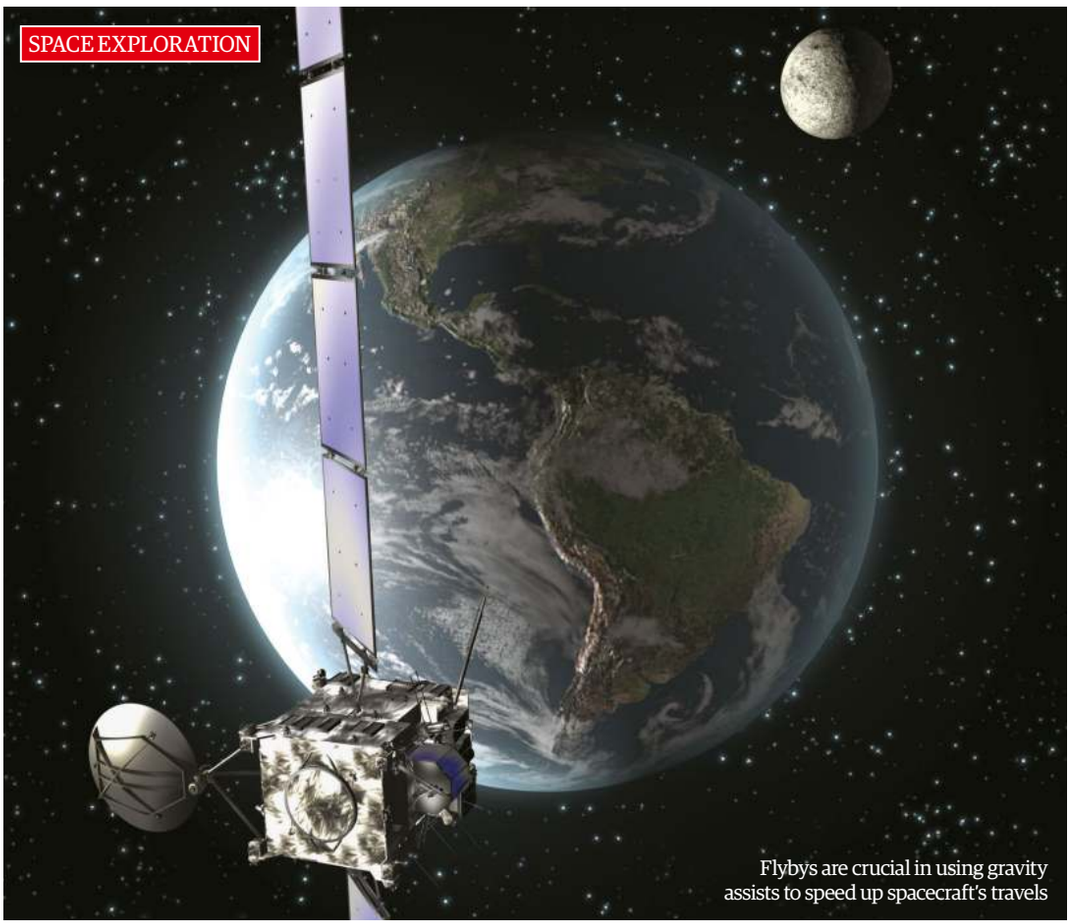
THE PLANETS

How did Saturn get its rings?

Imagine two ring particles – little chunks of ice – in contact with each other near Saturn. The planet's gravitational attraction is a little stronger on the particle closer to Saturn. This difference is called a tidal force, and is closely related to the tides in the oceans. Because of tidal forces it is difficult or impossible for a moon to form very close to a planet.

Saturn's rings are probably the remnants of a large icy body that formed elsewhere and was ripped apart when it came too close to Saturn. In one scenario, a moon like Titan spiralled in through the disc of gas and dust that surrounded the young Saturn. The moon's icy shell could have been torn off, with the fragments going into orbit around Saturn and the moon's rocky core being swallowed by the planet. The icy chunks would have collided and spread, with the particles close to Saturn becoming the ring system, and those that moved farther out coagulating into moons. In another model, a large Centaur – a body that escaped the Kuiper Belt – was torn apart by Saturn's tidal forces during a chance, very close passage. In a third concept, a moon of Saturn was destroyed by a comet impact. As in the first model, the fragments in these scenarios would have collided and formed rings and moons. Though the Cassini orbiter has vastly expanded our understanding of Saturn's rings, we still don't know which of these ideas is correct.

Luke Dones, senior research scientist at Southwest Research Institute's department of Space Studies in Boulder, Colorado



SPACE EXPLORATION

Flybys are crucial in using gravity assists to speed up spacecraft's travels

What's causing the flyby anomaly?

The flyby anomaly is featured on Wikipedia as an 'unsolved problem in physics' for a reason. We still do not know the cause of it, and although there are some candidate explanations none of them is doing the job. As possible classical effects contributing to this phenomenon we have: the atmospheric drag of low-orbit trajectories, ocean and solid tides, charging and magnetic moment of spacecraft by solar wind, Earth albedo, spin-rotation coupling, overlooked general relativity phenomena or thermal radiation. But the magnitude and sign of these perturbations seems insufficient for an explanation.

Perhaps it is something more strange, such as a dark-matter halo around the Earth or a modification of our cherished Einstein's theory of gravity. Another perplexing feature is the apparent disappearance of the anomaly in the flybys since 2005. So, only new data – perhaps from the Juno mission around Jupiter – could help in the discovery of its cause.

Luis Acedo Rodríguez is a scientist at the Institute for Multidisciplinary Mathematics in Spain

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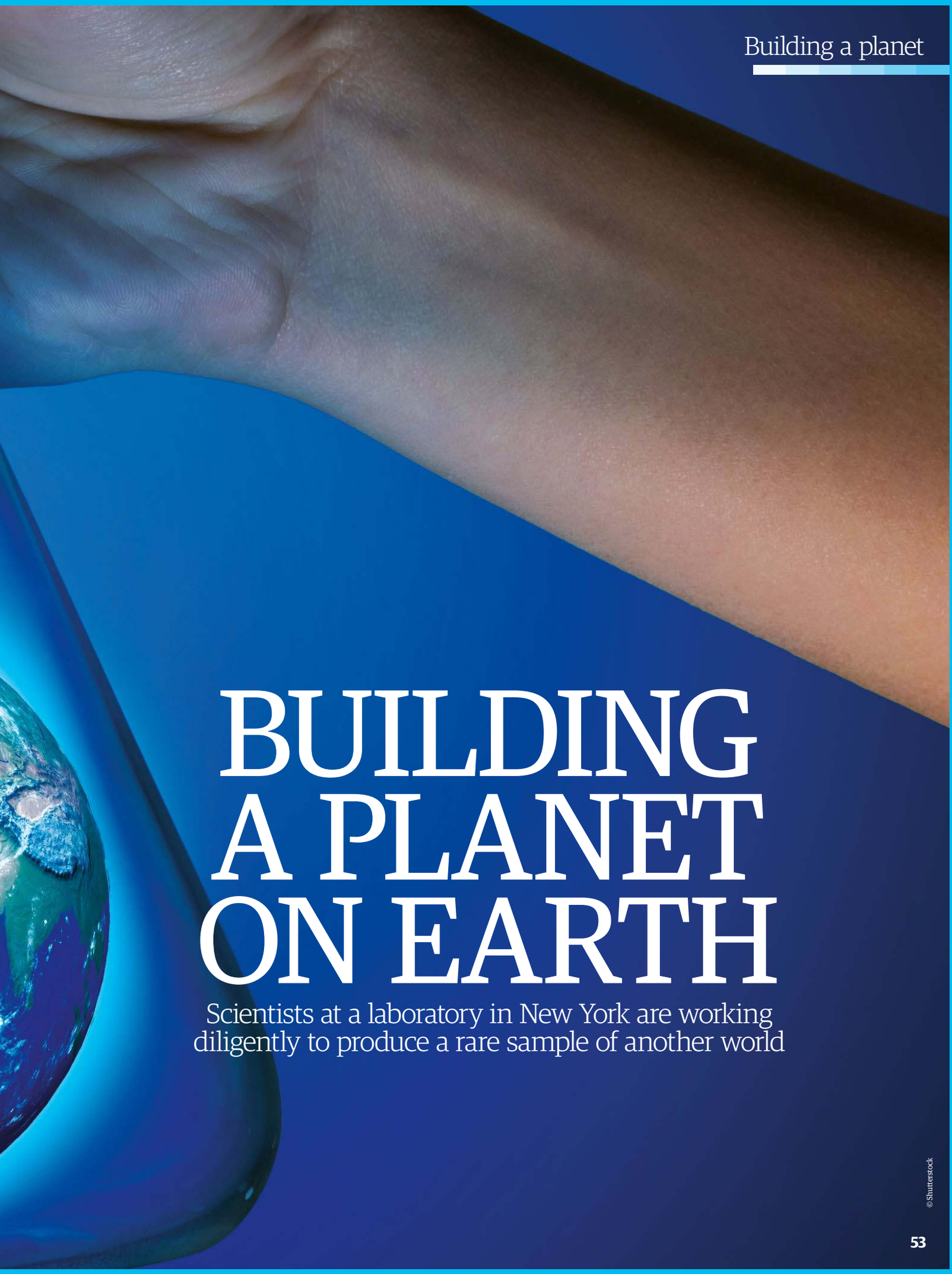


BUILDING A PLANET ON EARTH

Scientists at a laboratory in New York are working diligently to produce a rare sample of another world

Building a planet

Dr Mohamed Zaghoo is a research assosiate at the LLE

In Rochester, New York, United States, there is a laboratory that is home to the second most powerful laser in the world. This room can produce temperatures comparable to the core of the Earth, all in the name of research. This sanctuary of scientific research is the Laboratory of Laser Energetics (LLE), part of the University of Rochester's southern campus.

Within the LLE is the pièce de résistance, the OMEGA laser, which scientists are using to manufacture a new world. Within its target chamber, surrounded by 60 lasers, scientists are peering into the interior of gas giant planets such as Jupiter, Saturn and distant exoplanets that are primarily composed of the most abundant and simplest element in the universe: hydrogen.

Hydrogen, made up of one proton and one electron, makes up 74 per cent of the normal matter in our universe, with second place going to helium, which which makes up 24 per cent. These percentages are similar to our Sun, but the Jovian planets beyond the asteroid belt are also known to be made up of mostly hydrogen. Jupiter and Saturn both consist of about 90 per cent hydrogen, with the heavier elements sinking towards their respective cores and hydrogen dominating the residual layers, spanning tens of thousands of kilometres in radius.

On the face of each planet the layer of hydrogen that amateur astronomers can observe with a good telescope is hydrogen in its gaseous state, also known as molecular hydrogen (H_2). Molecular hydrogen is hydrogen in its most stable state and exists in a diatomic form; this is the state that scientists are most familiar with on Earth.

When you make your way towards the centre of a gas giant such as Jupiter, hydrogen turns into a more exotic state – metallic hydrogen. This is the state of hydrogen scientists are trying to create at the LLE, as Dr Mohamed Zaghoo, a research associate at the LLE, tells **All About Space**: "This is indeed a very exciting area of research where laboratory data and space observation are equally valuable to build a more accurate picture of hydrogen-rich planets."

Much like how water changes state based on temperature, melting ice into liquid water and further evaporating into water vapour with a continual increase in temperature, gaseous hydrogen will morph into its metallic hydrogen state with an increase in temperature and pressure. These conditions provide enough energy to pull the electrons away from their protons and form a sea of protons, which can also be thought of as hydrogen ions, and free-flowing electrons. As there are many free electrons shifting through this state of matter it is thought to be superconductive.

Metallic hydrogen is theorised and heavily supported – but not yet proven – to be the condition present in the inner layers of Jupiter and Saturn. It is also thought that by learning more about the metallic hydrogen state we can learn about a gas giant's magnetosphere and dynamo effect. A magnetosphere is the area occupied by a planet's magnetic field and the dynamo effect is the churning of conductive internal material powering the magnetosphere. Due to metallic hydrogen's superconductive nature, it would explain why Jupiter has the most powerful magnetosphere.

> "Laboratory data and space observation are equally valuable to build a more accurate picture of hydrogen-rich planets" **Dr Zaghoo**

The target chamber is a two-metre (six-foot) stainless steel sphere

Juno is situated at Jupiter, collecting vital data about the planet's magnetosphere

The OMEGA laser system is also used to initiate nuclear fusion

Understanding the apparatus

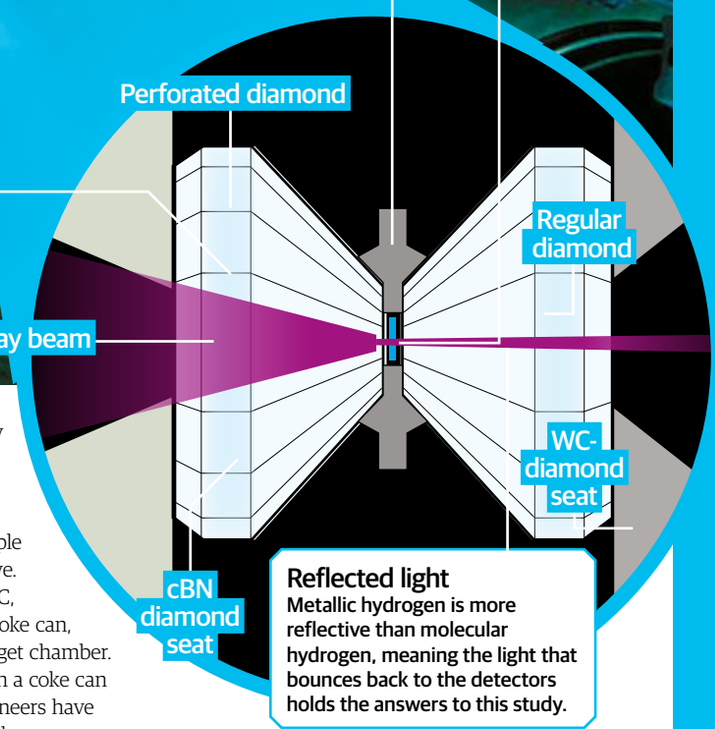
The OMEGA lasers and diamond anvil cells are vital when in creating this sample

OMEGA lasers
These lasers produce 30 kilojoules of energy in one-billionth of a second, heating the sample up to thousands of degrees.

Hydrogen sample
The hydrogen sample is only in the order of micrograms, but it is enough for scientists to carefully observe and study as it shifts into a metallic state.

Rhenium gasket
The gasket is a thin piece of material surrounding the sample in between the diamonds, acting as a seal in order to avoid leakage.

Opposing diamonds
Diamond is the hardest material in the world, making it ideal for applying as much pressure as possible with little deformation and cracking.



Metallic hydrogen is not easy to create, however. Pressure needs to be raised to between 1.4 and 1.7 megabar, and temperatures between 1,500 and 2,400 degrees Celsius (2,700 and 4,400 degrees Fahrenheit). This is over a thousand-times the pressure of Earth's average atmospheric pressure and these temperatures are capable of melting lead. These unearthly conditions are extremely difficult to manufacture, hence why this research is being conducted in one of the world's most unique laboratories.

In early 2017, Professor of Natural Sciences Isaac Silvera and postdoctoral fellow Dr Ranga Dias, both of Harvard University in Cambridge, Massachusetts, were actually able to create metallic hydrogen using a nifty but expensive piece of equipment called a diamond anvil cell (DAC). This is what was fitted at the centre of OMEGA's target chamber containing the hydrogen sample. "The diamond anvil cells generate the pressures statically, while the lasers [OMEGA] generate the temperatures," explains Zaghoo.

A DAC is a high-pressure device that has two opposing diamonds fixed together via rhenium gaskets. The diamond tips are polished to ensure there will be minimal cracks or damage that will lessen the pressure within the central sample region, which measures less than a millimetre. It is incredible to think that in a laboratory that stands ten metres (32 feet) tall and is approximately 100 metres (328 feet) in length, the culmination of the scientists' work all comes from a sample that is unperceivable to the human eye.

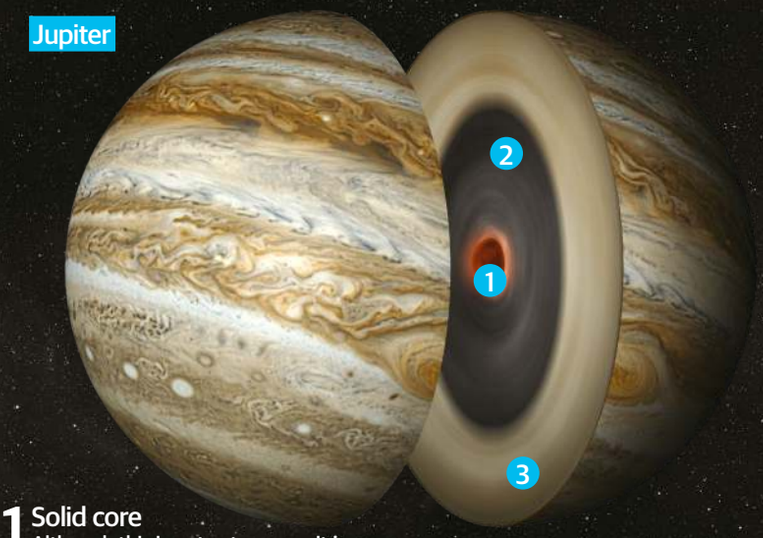
This sample is fitted within the DAC, which is approximately the size of a coke can, and then fitted inside the OMEGA target chamber. In the same way that people stamp on a coke can to squash it down, scientists and engineers have to squeeze the diamonds together and ramp up the pressure with each millimetre of compression. When this apparatus is fixed into position and the sample is under pressures comparable to the interior of Jupiter, researchers fire the lasers.

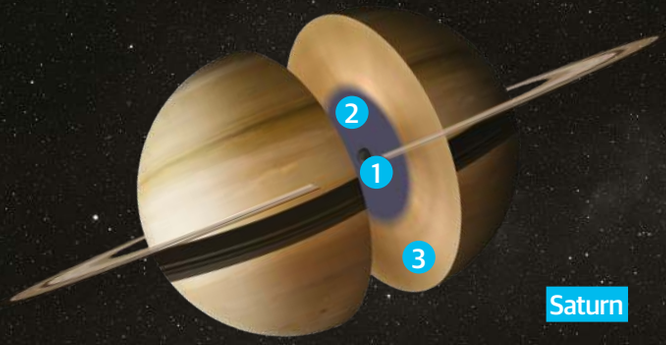
As the experiment room can rise to uncomfortable temperatures the scientists are situated in the LLE's control room when the heating begins. The OMEGA laser drivers are fired up, initiating the process by creating shaped seed pulses via a 60-beam ultraviolet neodymium glass laser, which are intensified with stage A amplifiers. By the time the lasers are concentrated on the target chamber OMEGA is capable of producing 30 kilojoules of energy and 60 terawatts of power in just one-billionth of a second. When compared with the fact that a standard oven can use up to 5,000 watts, the OMEGA produces 12 billion-times more energy in a fraction of the time.

Observations are the most essential part of any experiment, but it is impossible to observe any change with the naked eye. Because of this, researchers such as Zaghoo use an ingenious data-collection method. "The data is collected using fast optical detectors that record the reflectance of a laser light off the hydrogen samples. The premise of the measurements is simple: metallic substances reflect light, while insulating ones don't. Thus we measure how much light the compressed and hot hydrogen reflects," explains Zaghoo. "At low pressures and temperatures hydrogen is transparent liquid, but at sufficiently high pressures the molecular form of hydrogen breaks down under

Gas giants dissected

Hydrogen constitutes most of a gas giant planet, however, it exists in different forms





1 Solid core
Although this is not yet proven, it is theorised that the cores of Jupiter and Saturn are solid, dense collections of the planets' heavy elements collected during their formation.

2 Metallic hydrogen layer
The pressure and temperatures are great enough surrounding the core that hydrogen has taken the metallic state, creating the planet's dynamo and magnetosphere.

Earth

3 Molecular hydrogen
The outer layers of Jupiter and Saturn present hydrogen in its more common form, molecular hydrogen. The different colours of the cloud tops are due to the different elements in their composition, including methane, water vapour and ammonia.

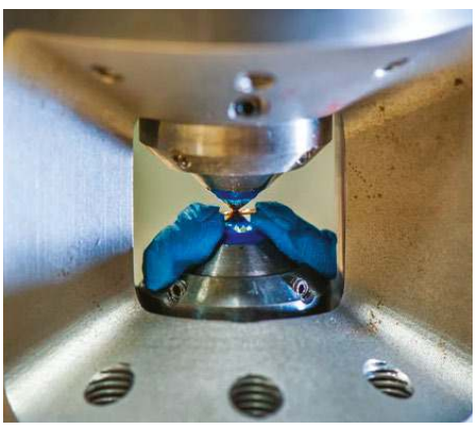
"At sufficiently high pressures the molecular form of hydrogen breaks down and gives away its electrons" **Dr Mohamed Zaghoo**

the crushing pressure and gives away its electrons, enabling conduction and light reflection."

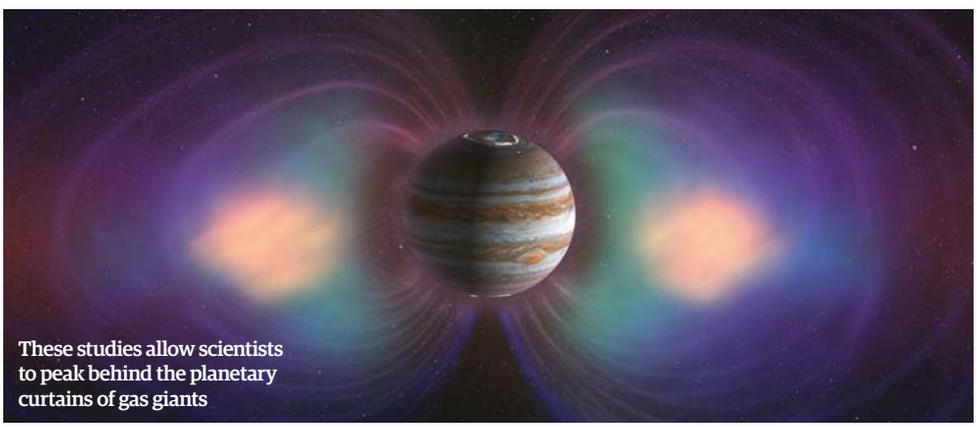
When the light is reflected back into their detectors scientists are overjoyed, yet there is still work to do. They have had a glimpse into the interior of gas giant planets – and in particular to this study, Jupiter – and after decoding the data they can uncover the mystery of their intense magnetospheres and dynamos. "By varying the final pressures and temperatures we were able to build this 'conductivity profile' or map of metallic hydrogen conductivity at different depths along Jupiter's interior," says Zaghoo. The conductivity map created in this instance has showed that Jupiter's dynamo originates closer to the surface than Earth's dynamo.

The research doesn't end there though. In science collaboration is key, and there are different missions with different perspectives that need to be accounted for. By incorporating these results into simulations that also include up-close observations from spacecraft like NASA's Juno mission – the space probe currently in orbit around Jupiter, gathering vital information about its magnetosphere and cloud top composition – scientists are continuing to understand the inner workings of Jupiter to a level that is simply incredible.

"One of the great insights that Juno very recently provided is that the thunderous winds, or bands, that characteristically distinguish the planet's surface extend much deeper into the planets interior, to almost 3,000 kilometres (1,900 miles) in depth," says Zaghoo. "By combining this data with our experimental conductivity profile we are able to further constrain the depth of the dynamo process and the interaction between the strong swirling winds with the conductive fluid deep inside."



Diamond anvil cells contain the hydrogen sample that is less than a millimetre long



These studies allow scientists to peak behind the planetary curtains of gas giants

AIRFIX

QUICK BUILD

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m² 16.70	kg 4,480	km/h 1,028
B km A 2,520	m/s 47	0.65

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A Model Aircraft
THE RAF RED ARROWS HAWK

The British Aerospace Hawk is one of the most important British jets. Having first flown as the Hawker Siddeley Hawk in Surrey in 1974 the Hawk is still in production in the UK today and is sold to many different countries all over the world. The Hawk is considered a "low-cost" combat aircraft, in 2003 one would've reportedly cost you approximately £18 million!

Without doubt, the most famous of the 1000+ BAe Hawks produced are the aircraft which wear the distinctive colours of the Royal Air Force Aerobatic Team 'The Red Arrows', arguably the world's best and certainly the most famous aerobatic display team.

The Red Arrows have been performing their thrilling displays to audiences all over the world since 1965, fulfilling the role of Britain's most effective flying ambassadors wherever they appear. To join the Red Arrows display team candidates have to have completed a front line tour as a Royal Air Force pilot, have a minimum of 1500 flying hours and be assessed as "above average" in their current RAF flying role. A maximum of three new pilots are chosen each year so the pilots of the Red Arrows really are the best of the best!

The Red Arrows have appeared in almost 5,000 displays in over 50 countries. A global television audience of over one billion people watched the flypast they performed at the London 2012 Olympic Games Opening Ceremony. The Hawks of the Red Arrows really are amongst the most famous aeroplanes in the history of aviation.

The Red Arrows Hawk is a British icon and you can recreate your own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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The space agency celebrates six decades of triumps and tribulations. **All About Space** highlights its best bits

Written by Ian Evenden

"The Hubble Space Telescope mission is clearly one of NASA's most internationally celebrated achievements. The genius of putting a telescope above Earth's blurring atmosphere has opened our eyes to a universe brimming with billions of galaxies, colourful star-forming nebulae and mysteries of dark matter and dark energy. Hubble is also revealing incredible activity in our own Solar System, and rich atmospheres of planets orbiting other stars, something never even envisioned when Hubble was first launched. The mission's success shows the power of NASA's diverse strengths working together, most notably through the several heroic astronaut servicing missions to Hubble. These have enabled the telescope to stay at the very forefront of scientific discovery even decades after launch, and we anticipate many good discoveries from Hubble for years to come."

Dr Jennifer Wiseman
Hubble Space Telescope senior project scientist
NASA's Goddard Space Flight Center

Explorer program

1 Explorer 1 was the first US satellite to go into orbit around Earth in 1958. Although it was first a military project, NASA took over the Explorer program with 1959's Explorer 6. The Explorer program is ongoing.

Modern Explorer missions are split into two main classes, Small and Medium. Medium missions were originally designed to be launched on a new, smaller, cheaper rocket, but this was never developed, and a modified Delta II is used instead. Examples include 1997's ACE, which is still operational and studying the solar wind's particles, and WISE, launched in 2009.

Small missions are even smaller, with a mission cost cap of $165m (around £130m) in 2017. Examples include the Sun-observing IRIS telescope, which has discovered plasma jets and tornadoes in the Sun's chromosphere.

Explorers will continue into at least 2019, and there's no reason to believe NASA is going to stop there.

Apollo program

4 When Kennedy made his speech, NASA had yet to put an astronaut in orbit. Development of the Saturn rocket launch system was accelerated, with the first unmanned test flight of a complete Apollo system taking place in February 1966.

Apollo 1 would follow, but suffered a disastrous fire during a launch rehearsal that killed all three astronauts on board. Further unmanned tests were carried out before Apollo 7 blasted off in October 1968, successfully orbiting the Earth for 11 days.

Apollo 8 would orbit the Moon in December 1968, returning TV pictures of the Moon's surface. Apollo 9 and 10 tested spacesuits and got closer to the Moon's surface than 8 had so that in the summer of 1969, all was set for landing.

Project Mercury and the Seven

2 It took less than a year for the US to catch up after the USSR put Yuri Gagarin into orbit on 12 April 1961. Project Mercury was already in existence, and succeeded in a sub-orbital flight, carrying Alan Shepard, on 5 May 1961. John Glenn would follow, orbiting the Earth three times on 20 February 1962.

20 unmanned flights were completed, of which three were launched after the manned flights. Some also carried animals, including a chimpanzee called Ham who was recovered from the Atlantic Ocean with no ill effects.

Mercury astronauts would eventually rack up 53 hours, 55 minutes and 27 seconds in orbit over six flights, and became the backbone of future NASA missions.

Apollo 11

5 The USSR had plans to land cosmonauts on the Moon in September 1968. Unfortunately for the Soviet space programme, its senior rocket engineer died in 1966, and this, along with a lack of funding, led to the project being delayed.

Neil Armstrong, Buzz Aldrin and Michael Collins reached the Moon on 19 July 1969, entered orbit and prepared to land, making history for the Apollo Program and crowning the US the winners of the long-fought Space Race.

Pioneer

3 The first spacecraft to explore the Moon were launched between 1958 and 1960. Pioneer 5 was fired towards Venus, and confirmed the existence of interplanetary magnetic fields.

Pioneers 6, 7, 8 and 9, launched by NASA between 1965 and 1968, orbited the Sun at distances between 0.8 and 1.1 AU, and were able to make detailed measurements of the solar wind.

Pioneer 10, launched in March 1972, was the first spacecraft to traverse the Asteroid Belt, and took a close approach to Jupiter in December 1973. Pioneer 11 went one better and encountered not only Jupiter, but Saturn as well. Launched in April 1973, it flew past Jupiter in late-1974, taking detailed images of the Great Red Spot. It reached Saturn in September 1979, passing just 20,921 kilometres (13,000 miles) from the gas giant.

Apollo 13

6 While Soviet interest in Moon landings dried up after Apollo 11, NASA kept on going. Apollo 12 made a successful landing in November 1969, despite lightning striking the launcher 36 and 52 seconds into its flight.

Apollo 13 launched in April 1970. Launch and module separation was successful, and the astronauts Jim Lovell, Jack Swigert and Fred Haise were 56 hours into the three-day trip to the Moon when they heard a bang and noticed their oxygen supply began to drain – they were forced to abandon their mission.

They retreated to the lunar module, using it as a lifeboat, and turned off all unnecessary electrical equipment. They continued to orbit the Moon, using its gravity to change their trajectory. The crew returned safely to Earth on 17 April 1970.

Viking

8 NASA returned to Mars in 1976 with Viking, a pair of probes designed to both orbit and photograph the planet, and this time to land. The USSR beat the Americans in landing a probe on another planet, having put Venera 3 on Venus in 1966.

Data from Mars was valuable, and Viking even carried experiments to look for life. While rovers explored the surface Viking's two orbiters continued their work above, taking more photos and acting as communications relays for the landers.

Skylab

10 Skylab was launched in May 1973, although it can't claim to be the first space station to orbit the Earth – the USSR got there first in April 1971 with Salyut 1.

Skylab was assembled in one piece on Earth and launched as the final mission of the Apollo program's Saturn V rocket. The station's three astronaut crews were ferried to the station in Apollo command modules launched on smaller rockets.

Mariner

7 Mariner sent robotic probes to the rocky planets between 1962 and 1973, and with each new mission we learnt more about our closest planetary neighbours.

NASA probed Venus' thick atmosphere with radio waves and sampled its magnetic field, and was able to confirm Venus was a hot, high-pressure world.

Mariner 9 was the first spacecraft to orbit another planet, photographing 85 per cent of the Martian surface, unveiling Olympus Mons along with canyons and craters, adding to the data and images from previous missions. Mariner 10 passed both Venus and Mercury on its journey.

"When I think about NASA's greatest achievements, I think about all the things NASA does to push the boundaries of impossible. Landing people on the Moon, sustaining human life in space and discovering the secrets of the cosmos through our awesome space telescopes, NASA helps us answer questions about our place in the universe, and what it means to be human."

Dr Amber Straughn
Astrophysicist
NASA's Goddard Space Flight Center

Voyager

9 An offshoot of the Mariner program, the twin Voyager probes were launched to the outer Solar System in 1977. Relying on a planetary alignment that occurs once every 176 years, the spacecraft were able to use the gravity of each planet they visited to align their trajectory to the next one.

Voyager 2 launched first, its mission to fly past Jupiter, Saturn, Uranus and Neptune. Voyager 1's route through the Solar System was shorter and faster, allowing it to investigate Saturn's moon Titan at the cost of being flung out of the Solar System without the chance of visiting other planets.

Voyager 1 overtook its twin in December 1977, passing Jupiter in March 1979 and Saturn in November 1980, flying past Titan as it entered the system.

Space Shuttle

11 The hugely famous and successful Shuttle Transportation System first flew in August 1977, but didn't undertake its first crewed mission until April 1981. Out of 135 launches two ended in failure, with the Challenger and Columbia disasters sadly taking 14 lives.

The Shuttle program would carry more than 350 astronauts to orbit. The programme enabled the construction of the ISS and Hubble; saw the first American woman in space, Sally Ride; the first untethered spacewalk; the first refurbishment of an orbiting satellite; the first launch of an interplanetary probe from orbit (Magellan); the first non-astronaut crew member... the list goes on.

"NASA's greatest accomplishment is being able to do things that no one else has ever done. NASA has sent humans to the Moon, created and operated the world's first reusable spacecraft and now transformed into an agency that is not only able to develop a spacecraft to take humans to Mars, but also support multiple commercial aerospace companies in their human spaceflight programmes to explore space."

Tom Engler
Director of the center planning and development office
NASA's Kennedy Space Center

Hubble

13 Launched in April 1990 aboard Discovery, Hubble's 547-kilometre (340-mile) altitude puts it well outside Earth's atmosphere, higher than Shuttles usually operate. Only Discovery's 1997 mission to boost the telescope's orbit has gone higher.

Along with producing beautiful images of the universe it has accurately measured the distances to Cepheid variable stars, allowing a more accurate measurement of the expansion of the universe, which also allows a more accurate estimate of its age.

Galileo

12 Galileo arrived at Jupiter orbit in December 1995, having released an atmospheric probe five months earlier. The probe flew ahead and survived for 57 minutes as it descended through Jupiter's cloud tops. It discovered Jupiter was denser, hotter and more radioactive than expected, with less helium than predicted and fewer cloud layers.

Meanwhile, in orbit, Galileo was able to confirm volcanic activity on the moon Io, find evidence for a liquid subsurface ocean under Europa, discover a thin atmosphere on three moons and detect a magnetic field on the moon Ganymede, the first moon to be shown to have one.

NASA's fleet of rockets

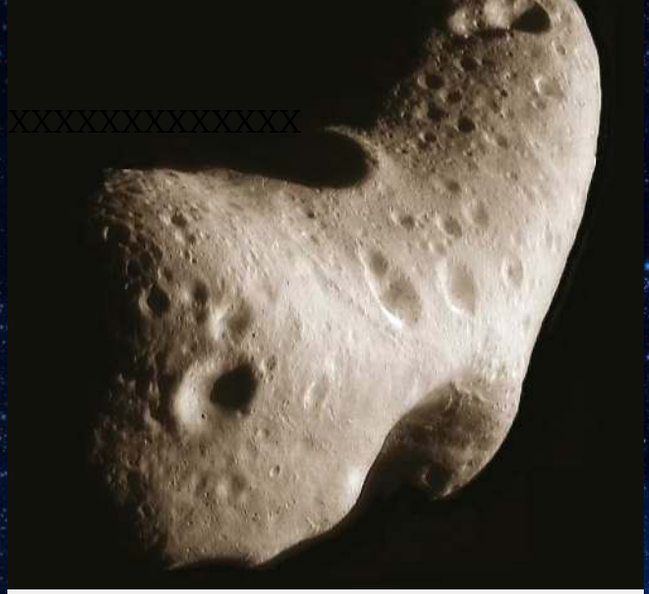
15 During the Cold War the political posturing of the Space Race was underpinned by military technology. The rockets used to propel men and machines into orbit were essentially missiles, and whoever had the largest and most successful missiles could consider themselves the winner.

NASA turned to the Saturn family, and chose the most powerful configuration available: the Saturn V. It remains the only launcher to take humans beyond Earth orbit.

Hubble repair mission

14 Hubble's giant mirror was very nearly its downfall. Initial images from the telescope were disappointing, and the fault was traced to the mirror's grinding and polishing process – one lens used to check the shape was out of position.

The response to this was a 1993 servicing mission, STS-61, that had been scheduled to go to the telescope for maintenance anyway. An instrument called the Corrective Optics Space Telescope Axial Replacement or COSTAR was added to Hubble, replacing one of its original instruments. As corrective optics, it was essentially giving the telescope glasses.



NEAR Shoemaker

16 Planets are quite big, but probes have managed to miss them with regularity, so when you're targeting something as small as an asteroid, the difficulty increases.

Near Earth Asteroid Rendezvous (NEAR) was launched in February 1996, named in honour of planetary scientist Eugene Shoemaker. Its primary target was Eros, an S-type (stony) asteroid that orbits the Sun on a path that takes it through the orbits of both Earth and Mars.

Following a year of orbital observations NEAR landed on the asteroid, lasting a further 16 days before being shut down. NEAR was the first in NASA's Discovery program, designed as low-cost launches that can be put together in less than three years.

NASA's Earth observations

18 NASA achievements don't always look outwards to deep space or the Solar System... sometimes they are looking back at Earth.

The Earth Observing System (EOS) began in 1999 with the launch of ACRIMSAT, which measured the energy being received from the Sun. It was able to view the 2004 transit of Venus and measure the approximate 0.1 per cent reduction in output caused by the planet crossing the solar disc.

There have been 26 satellites in the EOS constellation, not all active at the same time, studying things such as the ozone layer, the weather, Earth's magnetosphere and ocean surface currents. EOS is the centrepiece of NASA's Earth Science research, hoping to improve the prediction of weather and climate change, as well as enabling rapid responses to natural hazards.

"NASA's discoveries of the chemical building blocks of life on early Mars will help shape the search for life on the Red Planet. The coming decades will be exciting as we continue to explore and begin to develop the next generation of life-detection instruments."

Dr Mary Beth Wilhelm
Research scientist at NASA's Ames Research Center in Silicon Valley

Ed White's spacewalk

17 Project Gemini was NASA's second manned spaceflight programme, slotting in between Mercury and Apollo. Its two-man crews never went beyond low-Earth orbit, but their work laid the foundations for Apollo's trips to the Moon.

Gemini 4 was the second manned launch of the system and saw White and his commander James McDivitt become the first crew to spend multiple days in space. This was also the first spacewalk, with White tethered to the capsule and using a handheld oxygen cylinder to provide thrust. The walk lasted 23 minutes, with White at the end of an eight-metre (26.2 foot) tether.

New Horizons

19 In the nine years it took New Horizons to reach it, Pluto was downgraded from a planet to a dwarf planet, but this made no difference to the mission. It passed through the Pluto system in July 2015, accumulating so much data that it took 15 months to send it all back to Earth.

Pluto was a fuzzy, indistinct world even when imaged by Hubble, but thanks to New Horizons it snapped into focus: a red-and-white world largely covered in nitrogen ice, so cold that water takes the place of rock. The probe discovered a thin atmosphere of nitrogen, methane and carbon monoxide, before passing through the system and into the cold, mysterious Kuiper Belt beyond.

Being founded as a civilian agency

20 It would have been so easy in 1958, at the height of the Cold War, with Sputnik 3 being launched, Castro making revolutionary attacks in Cuba and Khrushchev taking power in the USSR, for space exploration to be kept as a military project. But US President Eisenhower and the 85th United States Congress thought differently, and an act was passed creating a new civilian agency – NASA – that would have a scientific and technological role, as well as encouraging cooperation between nations.

Parker Solar Probe

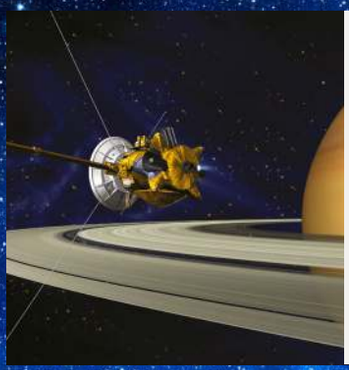
21 The Parker Solar Probe is getting closer to the Sun than ever before, with an ambitious plan to 'touch' the outer corona. The probe is designed to be highly automated as radio contact will take eight minutes, and the spacecraft will need to react more quickly to sudden changes in the Sun's output.

Its goals are to track the flows of energy within the Sun that heat its corona and power the solar wind. It hopes to determine the structure of the Sun's magnetic field, and determine how energetic particles are accelerated. Its orbits around the Sun will cross those of Mercury and Venus, and the probe will make seven flybys of Venus as it shrinks its orbit to get closer to the Sun.

Mars Exploration Rovers

23 The data that has been sent back to Earth from the mission has shown that Mars was once a wet planet, and that it is geologically active, with rocks of distinct chemical compositions analysed. One mineral in particular, goethite, only forms in the presence of water.

Spirit's mission officially came to an end in May 2011, although communication had been lost in March 2010. In May 2009 it had become stuck in soft Martian soil, and attempts to free it were unsuccessful.



Cassini-Huygens

25 The probe's objectives were to map the 3D structure of Saturn's ring system, determine the composition and history of each moon, study the atmospheres of both Saturn and its moon Titan and photograph everything it could.

Cassini provided the most detailed colour images of the giant planet yet seen, discovering atmospheric circulation in the impenetrable cloud banks.

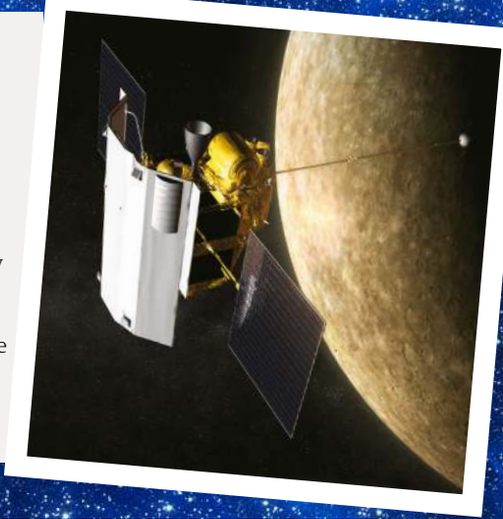
"The Space Shuttle ranks as one of NASA's greatest technical achievements. As the most complex machine designed, built and flown by human beings, it enabled hundreds of advancements in human, Earth and space sciences over its 30 years of service. It remains one of the best examples of what great things we can accomplish when we work together towards a common goal."

Matt Melis
Aerospace engineer at NASA's Glenn Research Center

Messenger

24 Mercury, thanks to its position relative to the Sun, is a difficult planet to study. MESSENGER had two solar panels that extended like wings from its sides and weighed more than a ton at launch – half of that was fuel. Inside, however, it was packed with instruments, and was protected by a highly reflective sunshade from the intense light and heat it would experience. It completed its mission in April 2015.

Once at Mercury, MESSENGER was able to confirm that there are water ice and organic compounds inside craters at its north pole, something suspected from Earth-based observations.



The International Space Station

22 A joint project between NASA, Canada, Russia, Europe and Japan, the International Space Station began life in November 1998 with the launch of its first module, Zarya, on a Russian Proton rocket. A Space Shuttle mission blasted off two weeks later carrying a second module, the American Unity module, and the two were connected together by spacewalking NASA astronauts.

From there, the station has bloomed to contain 15 modules and an Integrated Truss Structure to hold them all together. Continuously occupied for almost 18 years since the first crew arrived in November 2000, astronauts and space tourists from 18 nations have stepped aboard. The ISS provides a platform to test spacecraft technologies that may one day take humans back to the Moon or to Mars, along with prototype modules. The station houses laboratories operated by NASA, the ESA, Russia and Japan, as well as a seven-windowed observatory known as the Cupola, used to view the Earth and approaching spacecraft.

Stardust

26 Comet Wild-2, the target for Stardust, has been orbiting the Sun for 4.5 billion years and was discovered in 1978. An encounter with Jupiter in 1974 changed its orbit so it only took around six years, and brought it much closer to the Sun. Stardust reached the comet in January 2004, collecting particles from its coma, or tail.

Stardust returned to Earth and jettisoned its dust sample, which also included interstellar dust collected before the encounter with the comet. Over a million particles were analysed, showing a range of organic compounds, long-chain hydrocarbons and evidence for liquid water. There was even an amino acid, glycine, one of the building blocks of life.

Telstar

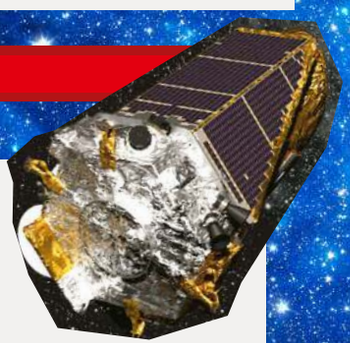
28 Just another communications satellite, but Telstar is important because it shows NASA's willingness to work with not just private companies, but other countries too.

Telstar did clock up a number of firsts after its July 1962 launch: it was first to relay TV pictures, telephone calls and faxes through space, and provided the first live transatlantic TV feed, featuring CBS's Walter Cronkite and NBC's Chet Huntley in New York, and the BBC's Richard Dimbleby in Brussels.

Mars Science Laboratory

29 Also known as the Curiosity Rover, the Mars Science Laboratory launched in November 2011. It is preparing the way for a manned expedition to Mars, investigating the planet's habitability, studying its climate and geology and measuring its surface radiation.

It landed in the Gale Crater, a depression caused by a meteor strike that at one point in its history was probably a lake. The crater was selected for both prior evidence of past water on Mars, and the richness of its mineral deposits. Curiosity has an onboard laser to blast samples of rock and soil, analysing the vapour that results.



X-15

27 The X-15 was a rocket-powered aeroplane that, by flying incredibly high and fast, qualifies as the first spaceplane, and its pilots as astronauts. It was operated by the US Air Force and NASA between 1959 and 1968.

Its liquid-fuelled rocket engines were similar to those used in space launchers, but the X-15 flew horizontally rather than vertically. It was carried aloft under the wing of a B52 bomber, firing its engines when at the required altitude. Because it was designed to fly at the top of the atmosphere, where the air is very thin, it had a thruster-based control system rather than the usual control surfaces, which would be ineffective at such a high altitude.

Kepler

30 While the first evidence of an exoplanet was logged in 1917, it wasn't recognised for the breakthrough it was. The first confirmed detection came in 1988, and since then almost 4,000 have been discovered.

The Kepler space observatory watches stars for evidence that they have planets. As a planet moves between its star and an observer, it causes a tiny eclipse. This leads to a drop in the brightness of that star and, no matter how tiny the drop is, it can be detected.

Kepler is part of the Discovery program of relatively cheap space missions, but has been hugely successful. It's responsible for over 2,300 of those 4,000 exoplanets, although while Kepler provides the data, actual confirmation of the planet's presence is carried out by scientists back on Earth, though, due to the amount of data Kepler produces, they're helped by algorithms.

"NASA astrophysics missions have opened our eyes to the universe beyond what we could have dreamed 60 years ago. From the iconic Hubble Deep Field to the discoveries by Kepler, NASA missions have given us fascinating discoveries that stretch the limits of our science, and our imagination."

Padi Boyd
Chief of the Exoplanets and Stellar Astrophysics Laboratory, and TESS project scientist at NASA's Goddard Space Flight Center

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LIFTOFF FOR THE MISSION TO TOUCH THE SUN

After a few delays, NASA's Parker Solar Probe has been launched and is headed straight for the Sun

The day finally arrived on 12 August 2018 for the Parker Solar Probe as NASA's historic mission to touch the Sun was launched from Space Launch Complex 37 at Cape Canaveral Air Force Station, Florida, United States. After some setbacks the day before, the Parker Solar Probe was eventually jettisoned on a United Launch Alliance Delta IV Heavy rocket at 3:31am EDT (7:31am UTC), just hours before the rise of the star it was off to study.

"This mission truly marks humanity's first visit to a star that will have implications not just here on Earth, but how we better understand our universe," says Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate. "We've accomplished something that, decades ago, lived solely in the realm of science fiction."

Being roughly the same size as a small car, the Parker Solar Probe is a mission that is highly anticipated by scientists around the globe. What this spacecraft can tell everyone about the Sun will be a catalyst for a new era of solar research, particularly in the field of space weather. The Sun randomly erupts highly energetic particles that permeate through space. It's important to get a better understanding of these particles, as the ones strong enough to reach Earth can be damaging to our electrical grid and even satellites, or cause potential harm to astronauts in space.

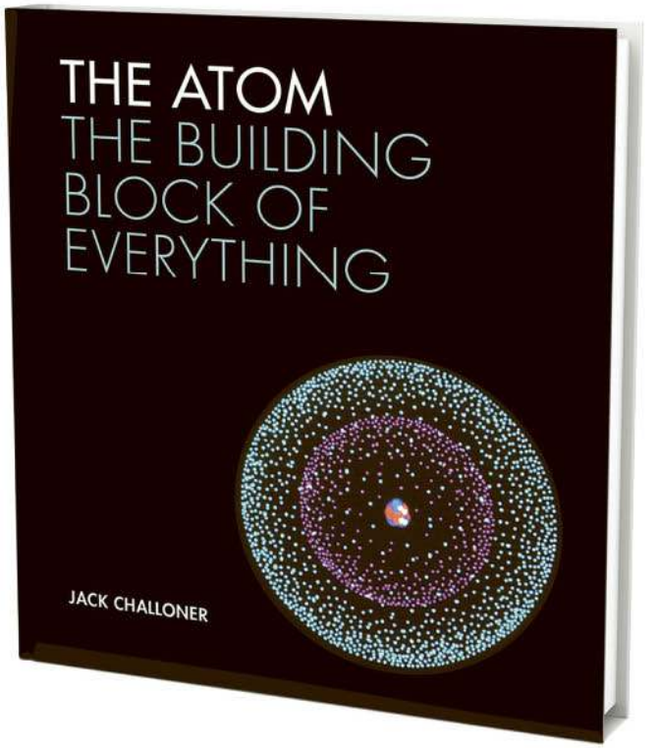
© NASA/Bill Ingalls

Dr Eugene Parker, a pioneer in solar research, watched his namesake spacecraft launch on 12 August 2018

Just over two hours after launch the mission operations manager reported that the spacecraft was healthy and operating as normal. This is the start of a journey that will last approximately seven years. After the successful launch the spacecraft will next deploy its high-gain antenna and magnetometer boom in its first week in space – the first of a two-part deployment of its electric-field antennae. In September 2018 there will be four weeks of instrument testing and, providing that everything is up to standard, science operations can begin. The overall journey will consist of six flybys of Venus and 24 passes though the Sun's local environment. The closest approach that the Parker Solar Probe will make will take it within 6.1 million kilometres (3.8 million miles) of the Sun's photosphere, travelling as fast as 700,000 kilometres per hour (430,000 miles per hour).

The Sun's corona is a constant thorn in astronomers' sides, as it is such a mystery. The corona is the layer of plasma that surrounds the Sun and has extreme temperatures succeeding a million Kelvin (millions of degrees of Celsius), which is far hotter than the star's inner photosphere. This is the equivalent of getting hotter as you step further away from a fire, which is ridiculous in principle. With the Parker Solar Probe flying closer to the corona than ever before, scientists can hopefully decrypt this code with the craft's pristine suite of instruments.

In attendance at the launch in the early hours of the day was Dr Eugene Parker, for whom the mission is named. Parker is an astrophysicist who laid the foundation to solar research and first theorised the existence of solar winds in 1958.



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Andy Brunning, chemistry educator and author of *Why Does Asparagus Make Your Pee Smell?*

"Jack Challoner's book on the venerable atom is a visually appealing introduction to the building block of the world around us. If you wanted a quick survey of the atomic realm, this book is a good place to start."

Don Lincoln, Senior Scientist, Fermilab; author of *The Large Hadron Collider: The Extraordinary Story of the Higgs Boson and Other Stuff That Will Blow Your Mind*

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STAR PARTIES

THE SURVIVAL GUIDE

Spending time with the night sky as well as like-minded people is what they're all about

Written by Jamie Carter

Eye-opening tours of the night sky conducted by an expert stargazer. The chance to look through huge telescopes and get close-ups of clusters, nebulae and galaxies. Staying up all night waiting for a particular object to be in the ideal position to observe. A star party is about all of this, and what's more, it's all in the company of like-minded people who share your passion for the night sky. But where do you start?

What is a star party?

Star parties come in various shapes and sizes. On the smallest scale they can be one-hour, often monthly get-togethers organised by a local astronomy club. At the other end of the spectrum there are full-on, week-long events with camping and trade stands selling eyepieces, binoculars and astrophotography accessories. Many star parties include guided stargazing events and talks, but just be wary of those that concentrate mainly on indoor lectures – these are more about learning than observing. Either way, do check what's planned. You can visit Dark Site Finder (**darksitefinder.com/map**) and enter the location of any star party. You'll instantly be able to see if the event is being held at a dark-sky site.

How to prepare

Even if you attend a star party at the height of summer, you'll be under dark rural skies where the heat of the day quickly escapes. It can get cold at night, especially during the early hours. Prepare as if you're stargazing in winter, taking a series of warm layers. Especially important is a long base layer that you can tuck into your trousers, since you'll likely be leaning back to look at the night sky through binoculars and telescopes. It goes without saying that you'll also need a warm coat, a scarf, a hat and gloves.

Who organises star parties?

Although often staged by local amateur astronomers, they're as likely to be promoted by the host venue, which could be a national park, campsite or sometimes a holiday park of cottages and chalets in a remote location. The best star parties have a lawn or meadow well away from the camping area that's dedicated to observing. Also, don't forget that most star parties are run by volunteers, so do be mindful to be polite and considerate of the basic rules of star parties. As well as some advice on how to make the most of your experience, we've included some mistakes to avoid that should mean you'll not only get your greatest education in astronomy yet, but you'll be sure to be welcomed back next time.

What you'll need...

1 Red-light torch
White light ruins everyone's night vision, so only bring a torch that has a red-light mode.

2 Binoculars
Although you can borrow some from other attendees, it's handy to have a pair around your neck.

3 Warm clothes
Since they're held after dark, star parties can mean standing still in cold weather, so dress warmly.

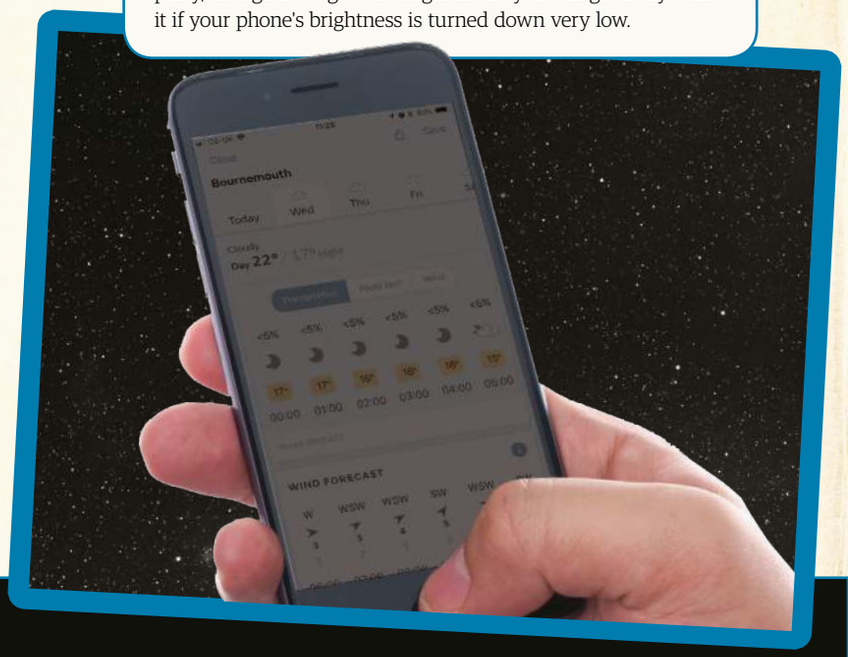
4 Snacks and drinks
It's very easy to spend many hours stargazing, so bring something quick and easy to eat and drink.

Red light is better

Red light doesn't affect night vision quite as much as white light, so if you do have to have a light on you at all, make sure it's red. A cheap head torch that has a red-light mode is a good idea, though don't plan on using it much; any kind of direct light in the eye of a dark-adapted observer will provoke anger. It's also a no-no to use even red light anywhere near astrophotographers, which you should presume are everywhere. However, if you do have to switch on a light, make sure it's red.

Resist your smartphone

Don't ruin your own night vision, as you'll just get less from the star party experience. No doubt you've got a great planetarium app on your phone that tells you exactly where all stars and constellations are in the night sky. Don't plan to use it at a star party, though if it's got a red-light mode you can get away with it if your phone's brightness is turned down very low.

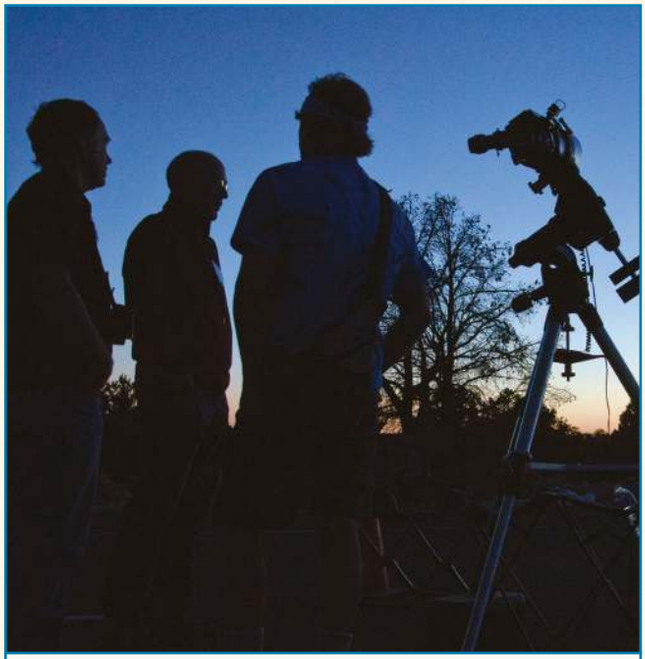


White light is the enemy

No white light. That's the rule around all star parties and any gathering of observers. Why? Night vision. After about 20 minutes in the dark, the human eye's pupil adapts by opening wider to let more light in. Dark-adapted observers can see so much more than those who have just stepped out of a brightly lit car. Consequently, a stray car headlight from late arrivers, any kind of torch or the light from a smartphone can instantly ruin everyone's night vision. That's saying nothing of astrophotographers who will be taking a long-exposure photograph - they don't want any stray light at any time. Arrive well before dusk and don't plan on returning to your car during the night; the light in the boot, as well as its headlights, could intensely annoy everyone at the star party. So park well away from the observing site, especially if you plan to leave during the night.

Ask for a guided tour

If someone produces a green laser pointer and begins pointing out stars, constellations and other celestial sights in the skies above you, you're in luck. Listening to someone effortlessly jump from one constellation to another can be a real delight for beginners, but also for the majority of amateur astronomers who don't have an encyclopaedic knowledge. If you find yourself in a muddle and you're not sure what you're looking at, ask if there's anyone around who could give you a short tour of the night sky so you can get your bearings. Another great tip is to always ask someone to point out exactly where the object you just saw through a telescope is in the night sky.



Ask lots of questions

If you've been learning about astronomy for a few months, or even a few decades, you'll probably have questions. Lots of them. The chances are that you'll be nervous about asking any questions, fearing that you'll seem unenlightened and out of place. Don't feel like that. Almost everyone that goes to star parties is there to share their passion and their knowledge. Besides, many experienced star partygoers only observe once a year, so are not that much more educated than beginners. There are no stupid questions at a star party.

> "Everyone is there to share their passion and their knowledge"

Take your own gear

You have a telescope? Take it along. It's not only a good time to get someone to help you with a problem you've been having, but you can also use a star party to swap eyepieces with other willing attendees. However, be sure to share something back; don't be that person that comes with nothing. Or, at least, don't always be that person. Going to a star party once per year is a great alternative to owning your own telescope, at least in your first few years of observing (and especially if you live in an apartment in a light-polluted city). There's no need to feel guilty if you go from 'scope to 'scope, saying hello and politely asking if you can look through the eyepiece. However, don't out-stay your welcome, and if you do find yourself hanging around a particular 'scope, offer to share some snacks, fetch a drink or help carry or set up gear.

Make the most of your trip

Here's how to make sure you get the very best experience at a star party

1 Get a sky tour

The chances are that someone at the star party will conduct a tour of the night sky using a laser pointer. If they don't, ask for one; if you're new to stargazing it will be the highlight of your evening.

2 Be inquisitive

Star parties are almost always held by people who want to share their knowledge with others, so feel free to ask any question you want without the fear of embarrassment.

3 Ask for buying advice

If you have decided to buy a pair of binoculars or a telescope, a star party is an excellent opportunity to ask experts what they recommend. Be prepared to tell them exactly what it is you want to observe.

4 Photograph the Moon

Although most star parties take place around new Moon, if there is a crescent Moon around, ask someone with a big telescope to let you take a photo through the eyepiece using your phone. It's easy!

5 Arrange a daytime meet-up

Star parties can be a great place to meet people, but since it's dark you can easily go home without knowing anybody's face. Arrange a meet-up, most likely at the next meeting of the local astronomy association.

Star parties near you

Fancy attending one yourself? These events from around the world are all worth the trip

Jasper Dark Sky Festival
Where: Jasper National Park, Alberta, Canada
When: 12 to 21 October 2018
Expect astronauts, astrophotography and nightly guided stargazing at this ten-day star party in the Canadian Rockies.

Kielder Forest Star Camp
Where: Kielder Water and Forest Park, Northumberland, UK
When: 10 to 15 October 2018 & 6 to 11 March 2019
Kielder Campsite in the Northumberland International Dark Sky Park hosts this twice-yearly gathering of amateur astronomers from all over the UK.

Grand Canyon Star Party
Where: Grand Canyon National Park's South Rim & North Rim
When: 22 to 29 June 2019
Eight days of free nightly astronomy programmes and telescope viewing with amateur astronomers from around Arizona.

Cherry Springs Star Party
Where: Cherry Springs State Park, Pennsylvania, US
When: 30 May to 2 June 2019
Run by the Astronomical Society of Harrisburg, this event takes place in an International Dark Sky Park.

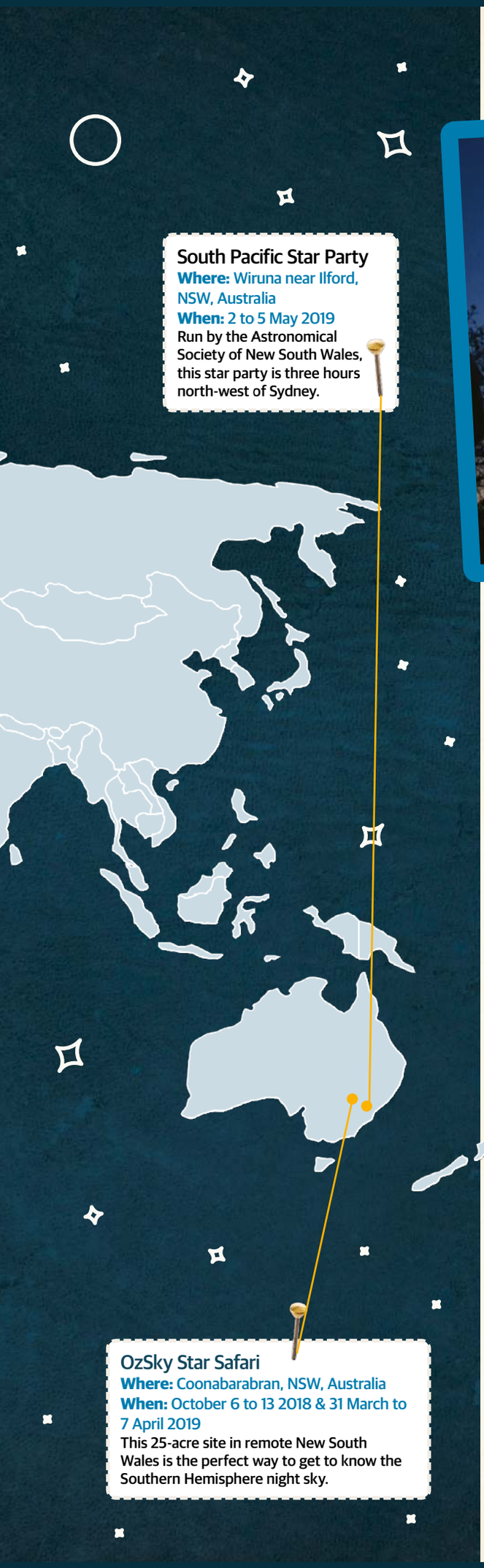
AstroCamp
Where: Brecon Beacons, Wales, UK
When: 8 to 11 September 2018 & 21 to 24 September 2019
This very relaxed three-day event each September & April at Cwmdu Campsite features a central lawn where amateur astronomers chat and set up telescopes.

Spring Star Party
Where: Kelling Heath, Holt, Norfolk, UK
When: 1 to 8 April 2019
Organised by the Norwich Astronomical Society, this star party has over 200 camping pitches and plenty of trade stands.

Winter Star Party
Where: Camp Wesumkee, Florida, US
When: 4 to 10 February 2019
Run by the Southern Cross Astronomical Society, this star party takes place in the Florida Keys.

International Telescope Meeting (ITT)
Where: Carinthia, Austria
When: 3 to 7 October 2018
Held on a meadow near Emberger Alm hotel, this star party in the eastern Alps is popular with astrophotographers.

"Make sure the object is in field of view, take your time refocusing the eyepiece and then take a good, long look"



Respect the telescopes

Every telescope at a star party is the pride and joy of the owner. Treat it carefully. If it's your first time with a telescope, tell the owner that and ask exactly what you should do. You may have to refocus a telescope to suit your eyesight, so ask the owner to show you how to do that. That goes double for Dobsonian telescopes, which tend to be rather large and consequently the centre of attention at star parties. Since they're manual they need repositioning every few minutes, so don't be afraid to tell the owner that you can't see the galaxy, nebula or planet at all. If you want to learn, don't just ask them to reposition it, but ask if they can teach you.

Wait your turn

If there's a long queue of people waiting to use a telescope, wait your turn. However, when you get to the front and it's your time to peer through the eyepiece, don't feel like you have to rush. After all, that's why you came. Make sure the object is in the eyepiece, take your time refocusing the eyepiece to suit you and then take a good, long look. If it's a star or planet, look straight at the object; it's the centre of your eye that sees colour. For a star cluster, scan around the field of view. If it's a nebula or galaxy, look slightly to the top and bottom of the object; your peripheral vision best sees brightness. After you've had a good look feel free to talk to the owner, but understand that they will also be giving advice to the queue of people.

Meet up in the day

If you've had a great time at a star party, don't just plan to go back next year. If it's near where you live, ask if there are any monthly meetings or observing sessions planned for other times of the year. It's also a strange fact that even if you spend a few hours chatting to someone at a star party, the next morning you likely won't recognise them. So walk around the observing field the next day, or arrange a meet-up later; having met people with the same hobby as you, don't keep them in the dark.

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

In this issue...

What's in the sky?

14 SEP
Conjunction between the Moon and Jupiter in Libra

14 SEP
The Moon and Jupiter make a close approach, passing within 4°10′ of each other in Libra

18 SEP
Asteroid 30 Urania at opposition in Pisces

20 SEP
The Moon and Mars pass within 4°43′ of each other in Capricornus

21 SEP
The Piscids reach their peak of five meteors per hour

24 SEP
Barred-irregular galaxy NGC 55 in Sculptor

2 OCT
Andromeda's second-brightest galaxy M32 is well placed for observation

3 OCT
The Sculptor Galaxy (NGC 253) is well placed for observation in Sculptor

4 OCT
The Moon and Beehive Cluster (M44) make a close approach, passing within 0°54′ of each other in Cancer

Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

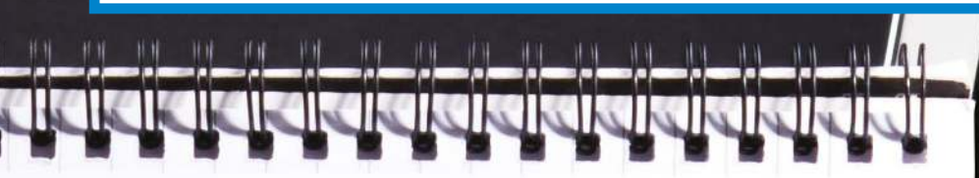
Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

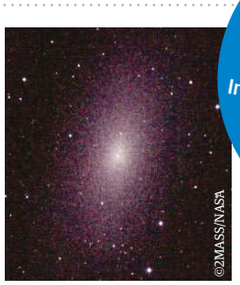
Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.



17 SEP
Conjunction between the Moon and Saturn in Sagittarius

17 SEP
The Moon and Saturn make a close approach, passing within 2°03' of each other in Sagittarius

23 SEP
September equinox



25 SEP
Venus reaches its brightest in the evening sky, dazzling at magnitude -4.6

27 SEP
Globular cluster 47 Tucanae is well placed for observation in Tucana

1 OCT
Andromeda's brightest satellite galaxy M110 is well placed for observation

7 OCT
Globular cluster NGC 362 is well placed for observation in Tucana

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

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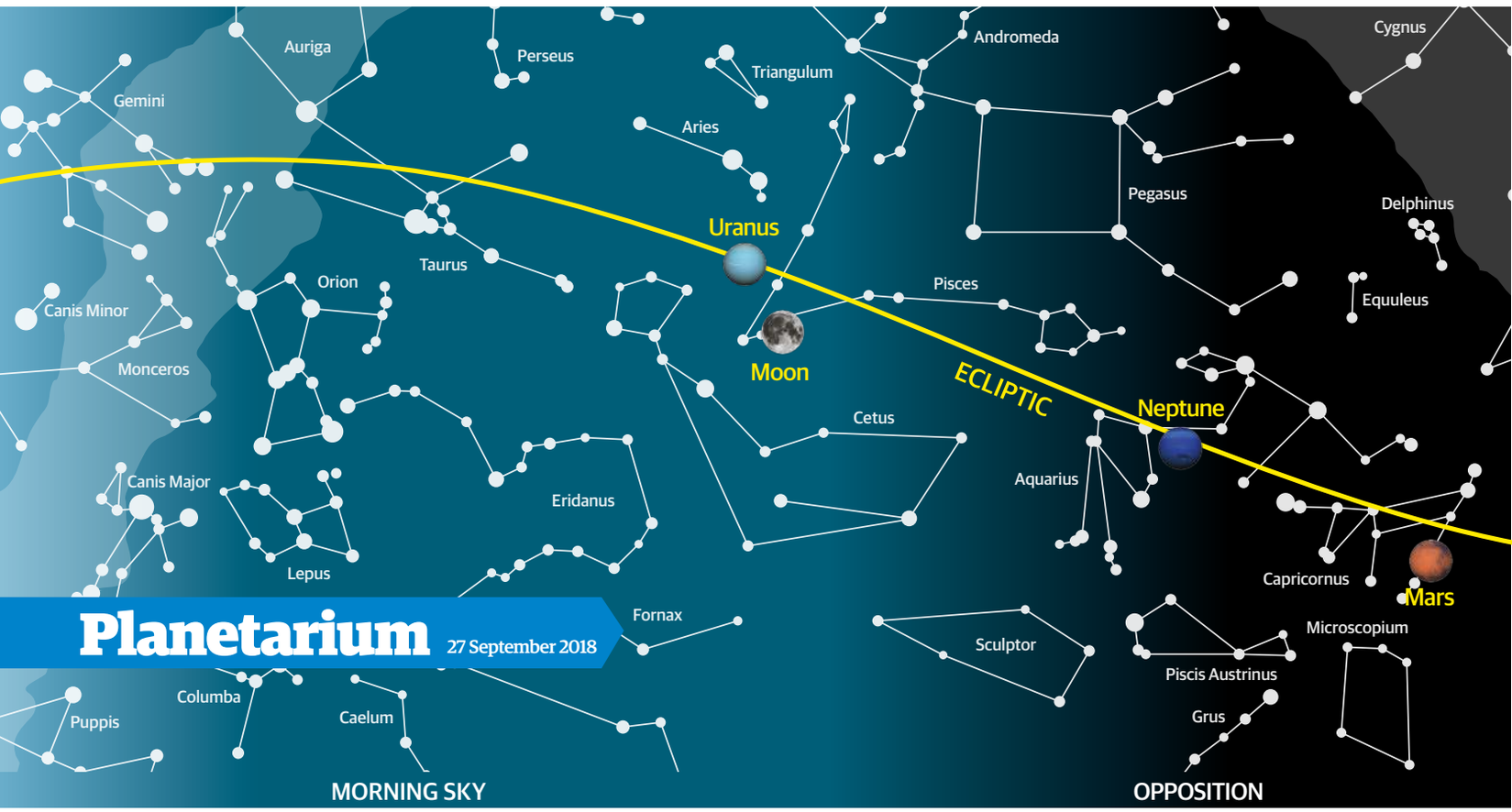


Planetarium

27 September 2018

Moon calendar

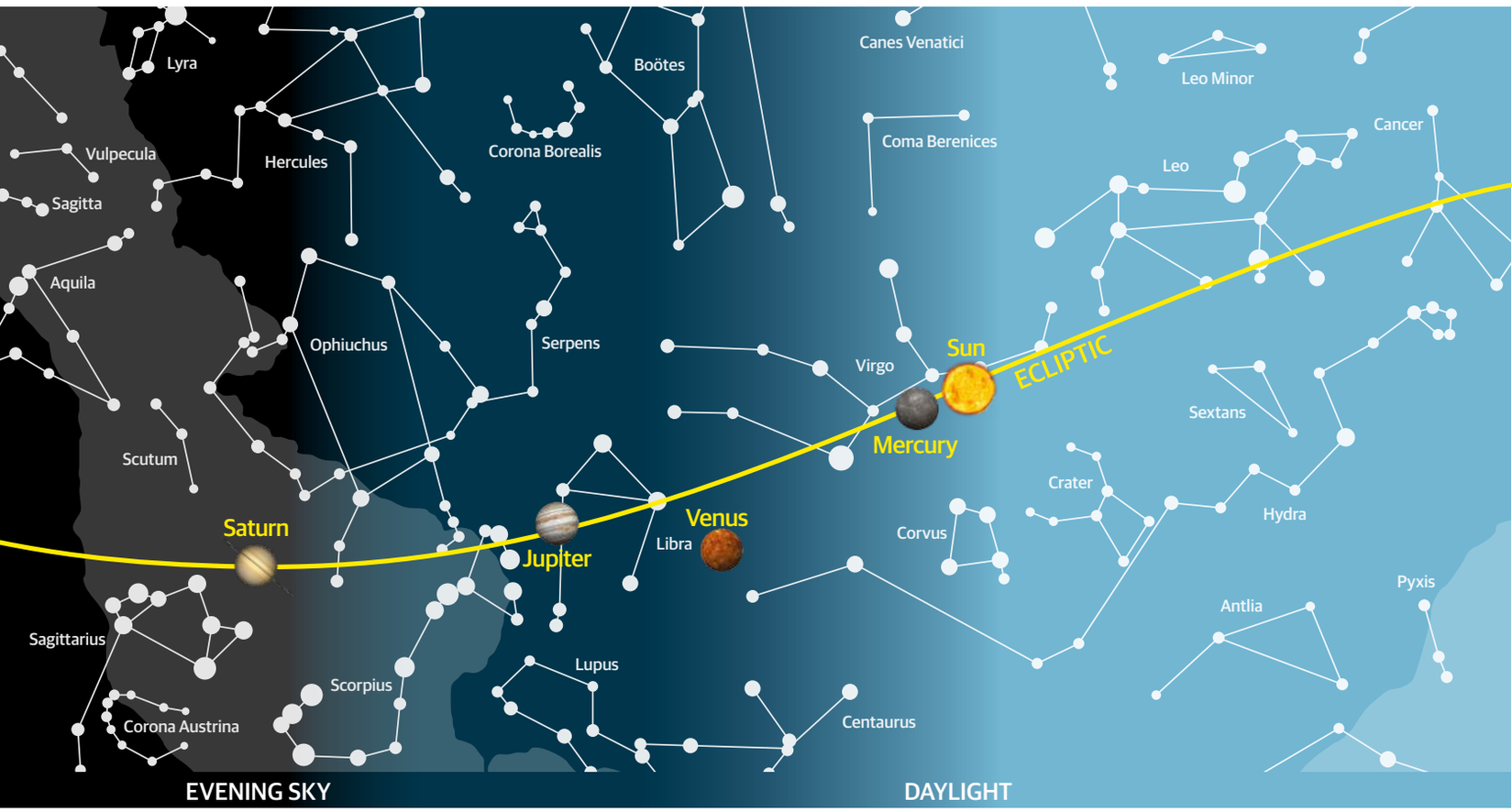
* The Moon does not pass meridian on 23 September

13 SEP 18.8% 10:53 21:24	**14 SEP** 27.9% 12:05 21:52	**15 SEP** 37.8% 13:13 22:23	**16 SEP** 47.9% 14:17 23:00			
17 SEP FQ 57.8% 15:14 23:43	**18 SEP** 67.3% 16:05 --:--	**19 SEP** 76.1% 00:32 16:48	**20 SEP** 83.9% 01:26 17:25	**21 SEP** 90.4% 02:26 17:56	**22 SEP** 95.4% 03:29 18:22	**23 SEP** --.-*% 04:35 18:46
24 SEP 98.6% 05:42 19:08	**25 SEP** FM 99.8% 06:50 19:29	**26 SEP** 99.0% 08:00 19:50	**27 SEP** 95.9% 09:11 20:13	**28 SEP** 90.6% 10:23 20:39	**29 SEP** 83.3% 11:36 21:09	**30 SEP** 74.1% 12:48 21:47
1 OCT 63.5% 13:57 22:34	**2 OCT** TQ 52.0% 14:59 23:31	**3 OCT** 40.2% 15:53 --:--	**4 OCT** 28.8% 00:39 16:37	**5 OCT** 18.5% 01:54 17:14	**6 OCT** 10.1% 03:13 17:44	**7 OCT** 4.1% 04:33 18:11
8 OCT 0.8% 05:53 18:35	**9 OCT** NM 0.3% 07:12 18:59	**10 OCT** 2.6% 08:29 19:23	**11 OCT** 7.3% 09:44 19:50			

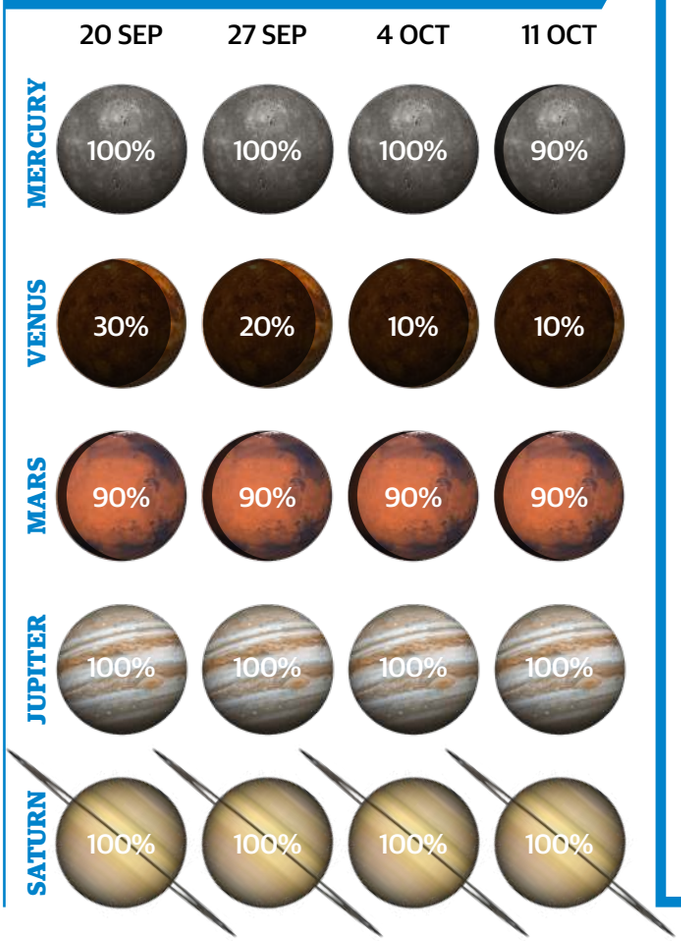
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

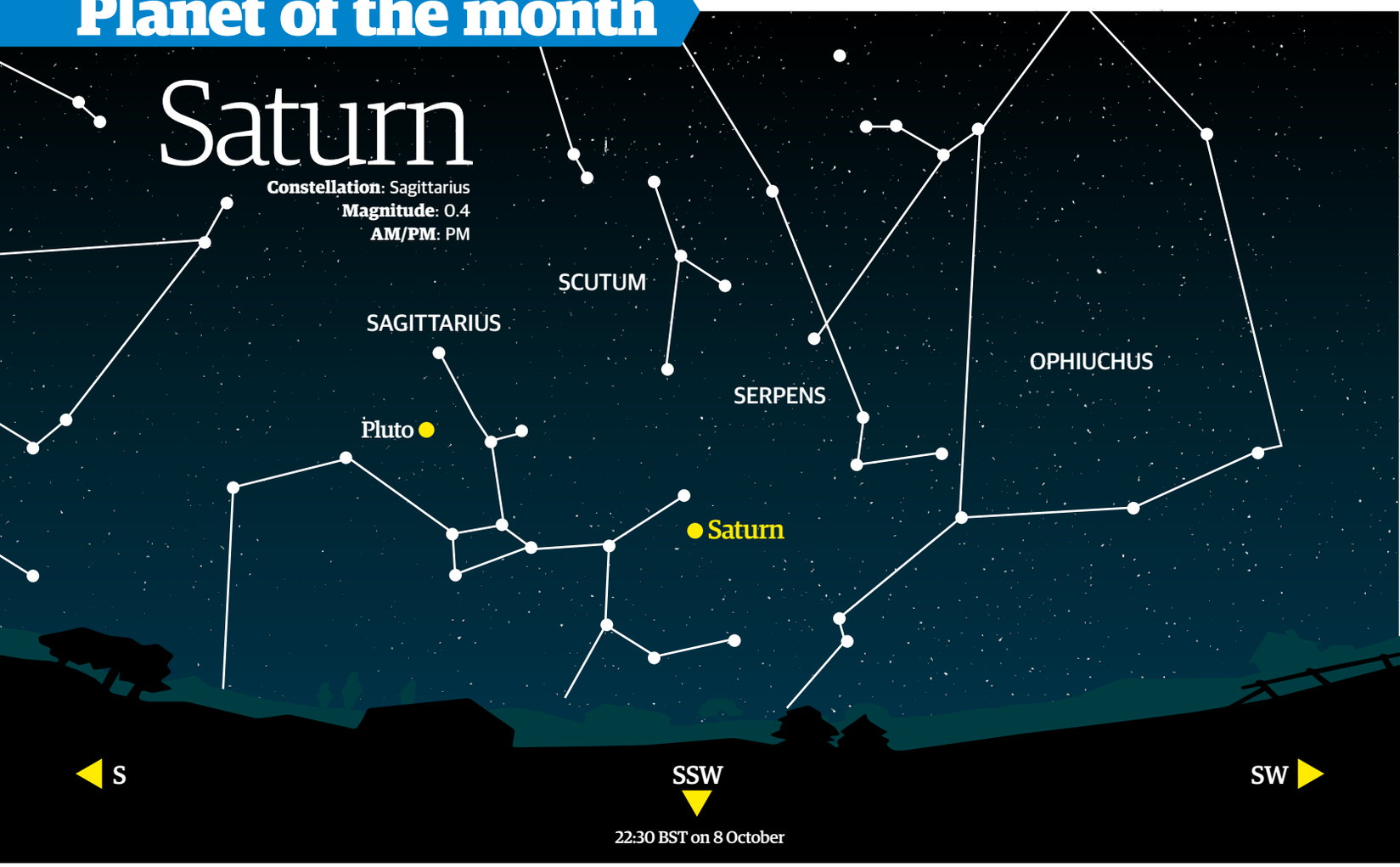
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	13 Sep	10h 58m 45s	+08° 29' 13"	Leo	-1.4	05:42	19:16
	20 Sep	11h 47m 08s	+03° 06' 14"	Virgo	-1.8	06:31	19:09
	27 Sep	12h 32m 16s	-02° 24' 22"	Virgo	-1.2	07:16	18:59
	04 Oct	13h 14m 46s	-07° 39' 30"	Virgo	-0.7	07:57	18:47
	11 Oct	13h 55m 37s	-12° 27' 30"	Virgo	-0.4	08:36	18:35
VENUS	13 Sep	13h 53m 20s	-16° 40' 21"	Virgo	-4.5	10:48	19:59
	20 Sep	14h 08m 04s	-18° 53' 58"	Virgo	-4.6	10:48	19:33
	27 Sep	14h 18m 23s	-20° 37' 23"	Virgo	-4.6	10:42	19:05
	04 Oct	14h 22m 54s	-21° 40' 54"	Libra	-4.5	10:26	18:35
	11 Oct	14h 20m 29s	-21° 51' 50"	Virgo	-4.4	09:57	18:04
MARS	13 Sep	20h 13m 56s	-24° 57' 39"	Capricornus	-1.8	18:01	01:28
	20 Sep	20h 21m 05s	-24° 08' 57"	Capricornus	-1.6	17:35	01:14
	27 Sep	20h 30m 18s	-23° 12' 22"	Capricornus	-1.4	17:10	01:02
	04 Oct	20h 41m 12s	-22° 08' 18"	Capricornus	-1.2	16:46	00:53
	11 Oct	20h 53m 30s	-20° 57' 00"	Capricornus	-1.1	16:23	00:45
JUPITER	13 Sep	15h 05m 53s	-16° 36' 12"	Libra	-1.9	12:00	21:12
	20 Sep	15h 10m 31s	-16° 56' 14"	Libra	-1.9	11:39	20:47
	27 Sep	15h 15m 28s	-17° 16' 57"	Libra	-1.8	11:18	20:22
	04 Oct	15h 20m 43s	-17° 38' 09"	Libra	-1.8	10:58	19:58
	11 Oct	15h 26m 14s	-17° 59' 36"	Libra	-1.8	10:38	19:34
SATURN	13 Sep	18h 10m 03s	-22° 43' 44"	Sagittarius	0.4	15:42	23:37
	20 Sep	18h 10m 33s	-22° 44' 37"	Sagittarius	0.5	15:15	23:10
	27 Sep	18h 11m 24s	-22° 45' 24"	Sagittarius	0.5	14:48	22:43
	04 Oct	18h 12m 34s	-22° 46' 02"	Sagittarius	0.5	14:22	22:16
	11 Oct	18h 14m 04s	-22° 46' 30"	Sagittarius	0.5	13:56	21:50

This month's planets

The ringed gas giant Saturn rules the evening skies this month, joined by Mars and Jupiter

Planet of the month



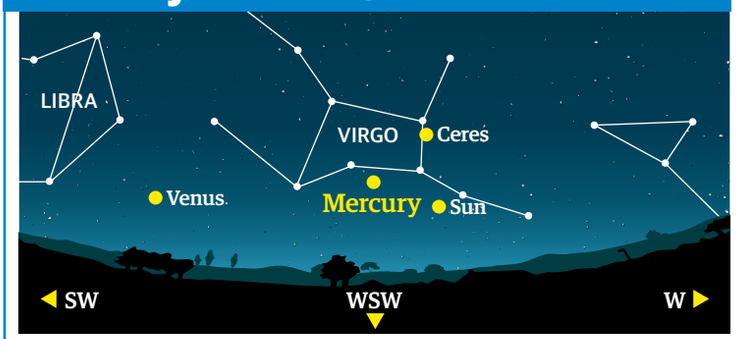
Even though it is quite faint and never gets very high in the sky, Saturn is still the planet best placed for observation this month. At magnitude 0.4 it is an easy naked-eye object, brighter than most of the stars in the sky, but its low altitude means it will appear fainter than that figure suggests. The planet is also embedded in the frothy star clouds of the Milky Way's almost-central region, so there is less contrast between it and the sky behind it, further reducing its immediate visual impact.

Saturn is still lovely to look at this month and is visible from sunset through to the late evening hours. To the naked eye it will look like a gold-hued star low in the southern sky during twilight, shining just above and to the right of the famous 'Teapot' asterism formed by Sagittarius' brightest stars. Binoculars will enhance its subtle warm colour, and if you have a small telescope you'll be able to see the planet's famous ring system wide open too, looking like a huge hula hoop thrown over the planet. The larger the telescope you look through, the more detail you will see within the rings; with enough magnification and a large enough aperture you will be able to see several dark gaps in the bright rings, and many of the planet's extended family of moons too. With a large telescope you will also be able to see some features on the planet itself, such as its dark pole, cloud bands on its disc and even the ink-black shadow of the rings cast on its disc.

A pair of binoculars or a telescope will also show you some interesting and well-known deep-sky objects close to Saturn. This month Saturn is never farther than two degrees – just four Moon widths – away from M8, the Lagoon Nebula, a huge cloud of glowing gas divided by a striking dark dust lane. This is a region in space where stars are being born, and you will see it as a small misty patch to the lower right of Saturn. Just above M8 is M20, another star-forming region known as the 'Trifid Nebula' because it is split into three distinct areas by its dust lanes. M20 is smaller and less obvious to the eye than M8, which is hardly surprising seeing as it is more than a thousand light years further away from us. Saturn will form an attractive triangle with both of these nebulae throughout the month.

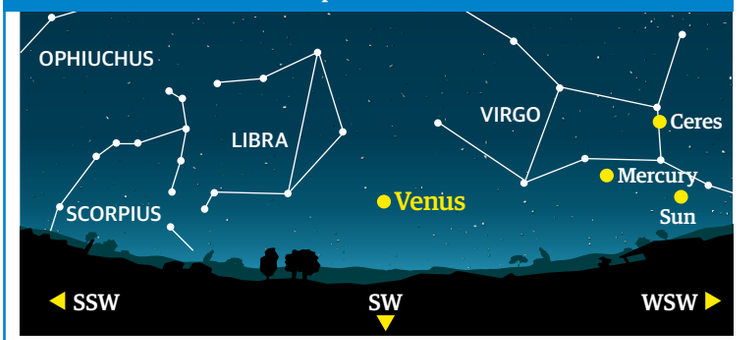
This month Saturn will also have a very attractive close encounter with the Moon. On the evening of 17 September the two worlds will be just two degrees apart, with the waxing gibbous Moon shining to the upper left of Saturn, making a very attractive pairing low in the southern sky.

Mercury 18:00 BST on 30 September



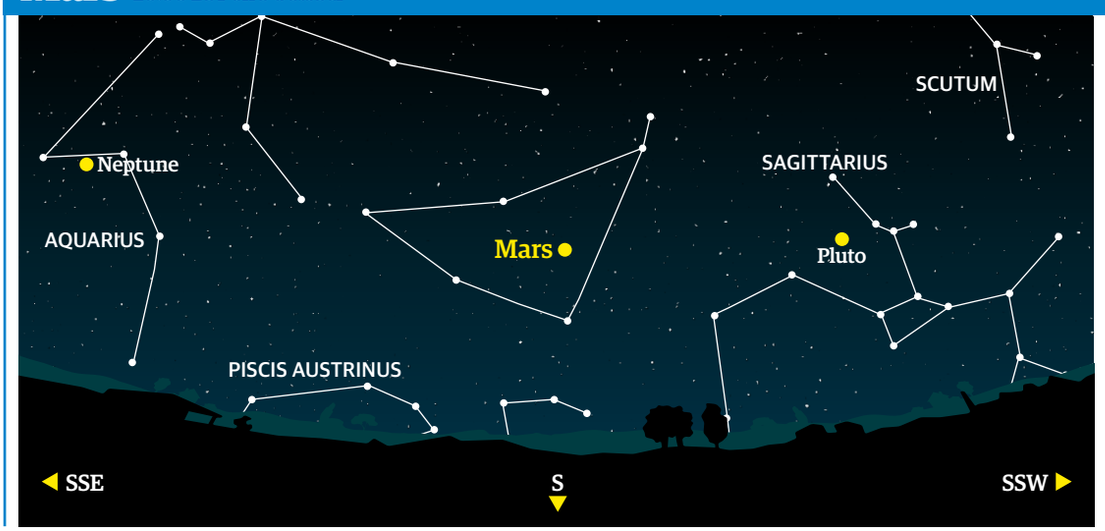
Constellation: Leo
Magnitude: -1.5
AM/PM: PM
Mercury begins the month technically in the evening sky, but is too close to the Sun to be visible. As the evenings pass it moves ever closer and closer to the Sun until it passes behind it. For the rest of our observing period Mercury will remain too close to the Sun to be visible without a huge amount of risk.

Venus 18:00 BST on 30 September



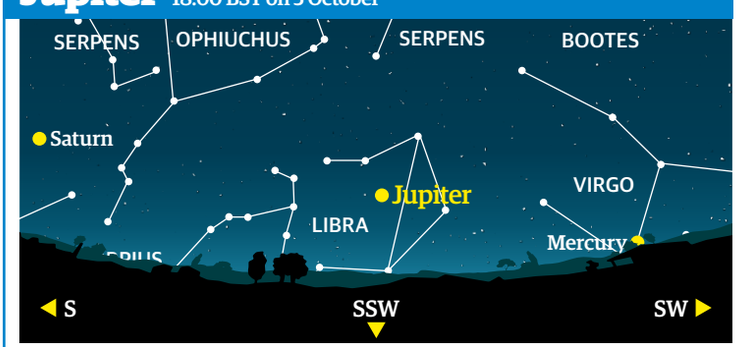
Constellation: Virgo
Magnitude: -4.5
AM/PM: PM
Venus is very poorly placed for observation this month. That magnitude of -4.5 is misleading because, at the start of our observing period, Venus is setting at around the same time as the Sun, so isn't easily visible despite its brightness, unless you are experienced in daytime planetary observing.

Mars 20:00 BST on 5 October



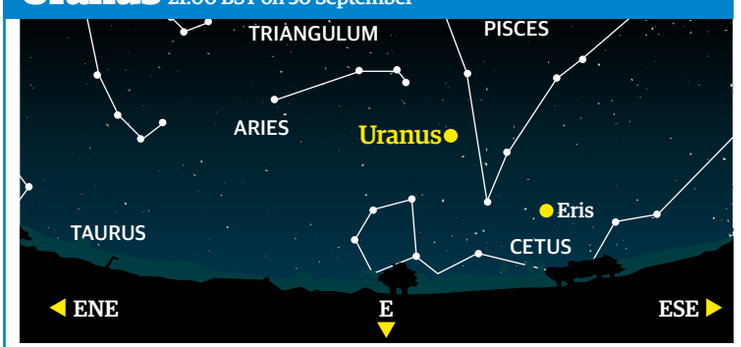
Constellation: Capricornus
Magnitude: -1.8
AM/PM: PM
Compared to how big and bright it appeared in the sky when it was at opposition, Mars is now a shadow of its former self, but it is still easily visible to the naked eye. Set among the unremarkable stars of the constellation Capricornus, and shining to the lower left of gold-hued Saturn, the famous Red Planet is visible from sunset through to midnight, tracing out a low arc above the southern horizon through the hours of darkness. Look for the Moon approaching and passing Mars between 18 and 20 September, with the two just six degrees apart on the evening of the 19th.

Jupiter 18:00 BST on 5 October



Constellation: Libra
Magnitude: -1.9
AM/PM: PM
At the start of our observing period it will set around 9:20pm, but by the end will set by 7:30pm, so your views of this giant world will be fleeting at best. Look for a lovely crescent Moon shining just six degrees to Jupiter's upper right after sunset on 13 September, and four degrees from it very low in the twilight on 11 October.

Uranus 21:00 BST on 30 September



Constellation: Aries
Magnitude: 5.7
AM/PM: PM
With a magnitude of 5.7 Uranus is technically visible without any assistance, but in reality you will need some help to track it down, unless you know exactly where to look. Using binoculars or a telescope will enhance the planet's green hue and help you pull it out from the starry background.

Top tip!

Albategnius is best seen when it is close to the terminator, around first or last quarter phase, when it is lit by the Sun at a low angle.

Moon tour

Albategnius

Gaze down into an ancient walled plain that puts some of the Moon's better-known features to shame

There are many features on the Moon that have acquired 'celebrity' status because they are genuinely impressive. Other features aren't given the same credit or attention because they are overshadowed by their more impressive neighbours. One such feature is a walled plain called Albategnius, which can be found almost in the centre of the Moon's face as we see it from Earth.

If you're not familiar with this feature that's no huge surprise. Albategnius is overshadowed by three huge and very famous features directly to its west: Ptolmaeus, Alphonsus and Arzachel. Linked together, and a striking sight in both a small pair of binoculars and a large telescope, these three craters are very popular observing targets, which is why poor Albategnius, just to their east, is usually overlooked. It's a shame, because it is a fascinating and rewarding feature.

Having said that, not everyone has ignored Albategnius. In 1610 Galileo observed it through his first telescopes and was so impressed by its appearance that he drew it, including it on his famous sketches of the Moon.

In modern times Albategnius has been observed and photographed in rather greater detail by many lunar probes, and in 1972 the crew of Apollo 16 took some beautiful images of it as they orbited the Moon on the fifth and penultimate Apollo mission to land on the surface of our planet's fascinating natural satellite.

Although Albategnius looks like a large crater at first glance it is actually classed as a 'walled plain', so it is more like a small sea surrounded by high walls than a simple crater. It is approximately 130 kilometres (81 miles) across, surrounded by jagged walls that tower more than four kilometres (2.5 miles) above the lunar surface, and has lots of smaller craters spattered across its deep floor, around 40 of them.

To the north of the crater floor a tightly clustered trio of these craters runs from west to east, itself presenting a very interesting sight through a small telescope. Albategnius also has another major crater inside its walls. Look down to the south-west and you'll see the crater Klein, a 43-kilometre (27-mile) steep-walled pit.

In common with many large craters, Albategnius has a central peak, a mountain that stabs up from its floor. Its summit is over 1.5 kilometres (0.9 miles) above the floor and topped with a small crater of its own. Some observers think the mountain range has the shape of a ghost or an angel – you'll need to look at it through your own telescope to decide if you agree...

Albategnius' walls are, like those of most large craters on the Moon, very complicated features in their own right, with multiple terraces and ledges breaking them up in every direction and criss-crossed and cut into by valleys and gorges here and there.

So, when can you see this intriguing if overlooked feature for yourself?

As our observing period opens Albategnius is invisible, still deep in shadow. It doesn't emerge from the darkness until 16 September when the terminator sweeps over it, surrendering it to the sunlight. A day later the plain will be fully visible, its high walls standing out starkly against the surface with the Sun's rays striking them at a low angle. By the time the Moon is full on 24 September, with the Sun blazing directly overhead, the plain will have been reduced to a mere dark patch. As the days pass and the terminator creeps back towards it from the east Albategnius will become more and more prominent again, until it is swallowed up by the darkness on 2 October and is lost from our view.

Why not take a look at Albategnius this month? True, there are larger and more dramatic features around it, but if you can drag your eyes away from those and dare to stray from the well-worn path you usually follow across the Moon, you'll find Albategnius a very rewarding 'off the beaten track' destination.

This month's naked eye targets

How to spot bright stars, weird stars and dead stars in October's sky...

Capella (Alpha Aurigae)
The brightest star in Auriga (the Charioteer), yellow-white Capella is also known as 'The Goat Star'. Shining at magnitude 0.07, almost as bright as better known Vega, it is the eighth-brightest star in the sky, and the closest first magnitude star to the Pole Star.

The Pleiades (Messier 45)
One of the most famous and beautiful objects in the night sky, the Pleiades is a cluster of stars 430 light years away from Earth. The naked eye can see its seven brightest stars – hence its nickname 'The Seven Sisters' – but it actually contains many hundreds of glittering blue-white stars.

Almaaz (Epsilon Aurigae)
The brightest member of a triangle of faint stars close to Capella nicknamed 'The Kids', Almaaz is a weird star. This huge blue supergiant star, 2,000 light years away, dims every 27 years for a period of two years as something huge and unseen passes in front of it, most likely a dust ring around another companion star.

Aries

Auriga

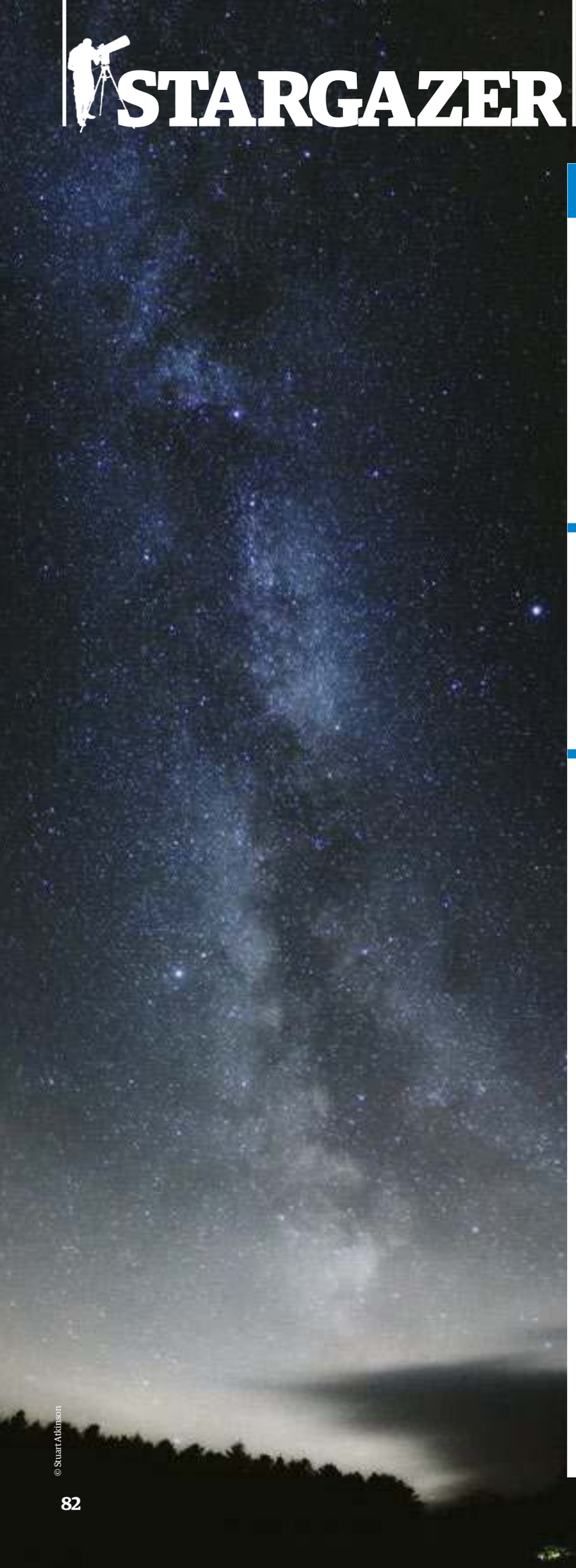
Taurus

Orion

Crab Nebula (Messier 1)
Binoculars are needed to see this fascinating object – the ghostly remains of a star that was seen to explode as a supernova on 4 July 1054. In fact, the star blew up 6,000 years earlier, as it is that many light years from Earth. Today the Crab Nebula is just a tiny eighth-magnitude smudge in binoculars.

The Hyades (Melotte 25)
This large star cluster is very obvious to the naked eye, with a distinctive 'V' shape. Confusingly Aldebaran, the bright, orange-red star at the end of its lower arm, is not actually a member of the cluster, it just lies along our line of sight to it.

Will Throp



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How to...

Photograph the Milky Way

This is the best time of year to photograph our galaxy. Here's how to take your own beautiful portraits with just a camera and tripod

You'll need:

- ✔ A dark-sky site
- ✔ A DSLR camera
- ✔ A wide-angle lens
- ✔ A tripod
- ✔ A cable release
- ✔ Photo-processing software

If you've ever looked at photographs showing the glittering star clouds and dark dust lanes of the Milky Way and thought 'I wish I could take something like that...', here's some good news – it's really not that difficult. All you need is somewhere with a dark sky, a basic DSLR on a tripod and the right settings.

Late September is one of the best times to photograph the Milky Way. By late evening its brightest and most photogenic areas are standing vertically above the south-west horizon, and you can take images showing them with the landscape beneath them, which gives a good sense of scale.

Finding a dark-sky site is important because you'll be taking time exposures and any light pollution will wash away the subtle glow of the Milky Way. The right lens is important, too. Although a standard 50mm lens will show a lot of stars, you'll need to use a wide-angle lens to capture the full glory of the Milky Way. An 18mm lens is good, but if you have a 10mm lens that will be even better. With your camera tipped on its side into portrait format you will capture lovely views of the Milky Way looking like a wide vapour trail in the sky. The Cygnus star cloud will stand out clearly, and the 'Dark Rift' running down beside it will be very obvious too.

ISO and exposure times are also very important. Set your camera to 800 ISO at first – you can always increase or decrease it after taking some test shots. With an 18mm lens you can take exposures of 20 seconds or so before the stars start to trail, and even longer with a wider lens. If you're not sure how long an exposure to use, just experiment.

Focusing properly on objects in the night sky can be hard, but luckily Mars will be big and bright in that part of the sky, so can focus on that before starting to take photos. You can also use a distant streetlight as a focusing aid.

Tips & tricks

Location, location, location

Find somewhere with no light pollution, no passing traffic and a clear view to the south west. Firm ground would be a bonus too.

Keep it tight

Make sure everything on your tripod is tightened up and fixed firmly in place before taking photos. The slightest slip will give you blurry photos.

Grab as much sky as you can

Use the widest angle lens in your kit bag. A standard 50mm lens will do, but you'll capture much more of the Milky Way with an 18mm or wider lens.

Keep your exposures short

Make sure you take exposures short enough to keep the stars as pinpoints. Expose too long and you'll get trails instead.

Getting ready to shoot

Take plenty of photos to ensure you get a great final result

Using a cable release to cut down vibrations, take a few test shots to check if your settings are working. If the stars have trailed, reduce the exposure time. If the Milky Way isn't obvious, increase the ISO. After a few tries you'll find a combination of settings that gives you great shots of the Milky Way. Keep those settings and take lots of photos. Some will be better than others, and you can stack those together later.

Send your photos to
space@spaceanswers.com

1 Ensure a steady platform

Mount your camera on a sturdy tripod to keep it as steady as possible. To prevent blurred photos, check nothing on your tripod moves or slips. Try and find flat ground, too.

2 Fit a wide-angle lens

Fit your camera with your widest angle lens and a cable release. Set it to Manual mode, an ISO of around 800 and an exposure time of 20 seconds. Set a time delay too if you can.

3 Position your camera

Pointing it towards the south west, turn your camera onto its side to give a portrait image. Focus sharply on either a bright star or a distant light on the horizon.

4 Alter the exposure time

Press the cable release to take your first image. If the Milky Way isn't clear try increasing the ISO or exposure time until it looks more obvious.

5 Shoot a series

When you have some images you are happy with, take a series of overlapping photos panning upwards to turn into a mosaic later when you are processing your images.

6 Alter the contrast

Use photo-processing software to increase the contrast and improve the appearance of your images, but don't go too far and make them garish or unrealistic.

Deep sky challenge

Tackle the sights of the Great Square

Hidden treasures wait to be found in and around a feature of Pegasus

The Andromeda Galaxy (M31) is one of the most famous and most frequently observed and photographed deep-sky objects in the whole of the night sky. And rightly so: easily visible to the naked eye as a smudge of light larger than the Moon, even a small telescope transforms it into a beautiful misty oval, while larger instruments reveal hints of its spiral structure, its bright central core and a pair of fainter satellite galaxies nearby.

But a short star-hop away from this celestial celebrity lies a handful of other objects worthy of telescope owners' attention. Much smaller, much fainter and much harder to see, they are nonetheless worth tracking down because they are so different to big, brash M31.

A couple of this month's challenges really are only worth looking for with large 'light bucket' telescopes under a sky unaffected by light pollution. Others will be glimpsed through smaller instruments. One is visible to the naked eye – but the reason it is included on our list this month would not even be visible through the largest telescope in the world. So why include it? Because, like many things in astronomy, the joy comes from the appreciation of what you're looking at, or for, and not the actual view itself.

The Little Sombrero (NGC 7814)

1 Mirach's Ghost (NGC 404)

Just 6' north of the bright star Mirach, this tenth-magnitude irregular galaxy can be glimpsed in small telescopes as a tiny smudge, but requires medium and large apertures to see it well.

2 The Taffy Galaxies (UGC 12914)

A real challenge even for large-aperture telescopes, this barely-there magnitude 13 galaxy is 163 million light years away. Expect to see nothing more than a dim, elongated smudge even at high power.

3 The Little Sombrero (NGC 7814)

This edge-on spiral galaxy owes its nickname to its resemblance to larger, brighter M104. At tenth magnitude it can be seen in small telescopes, but larger apertures will show it as an elongated misty patch with a dark central band.

4 Pegasus Dwarf Galaxy (UGC 12613)

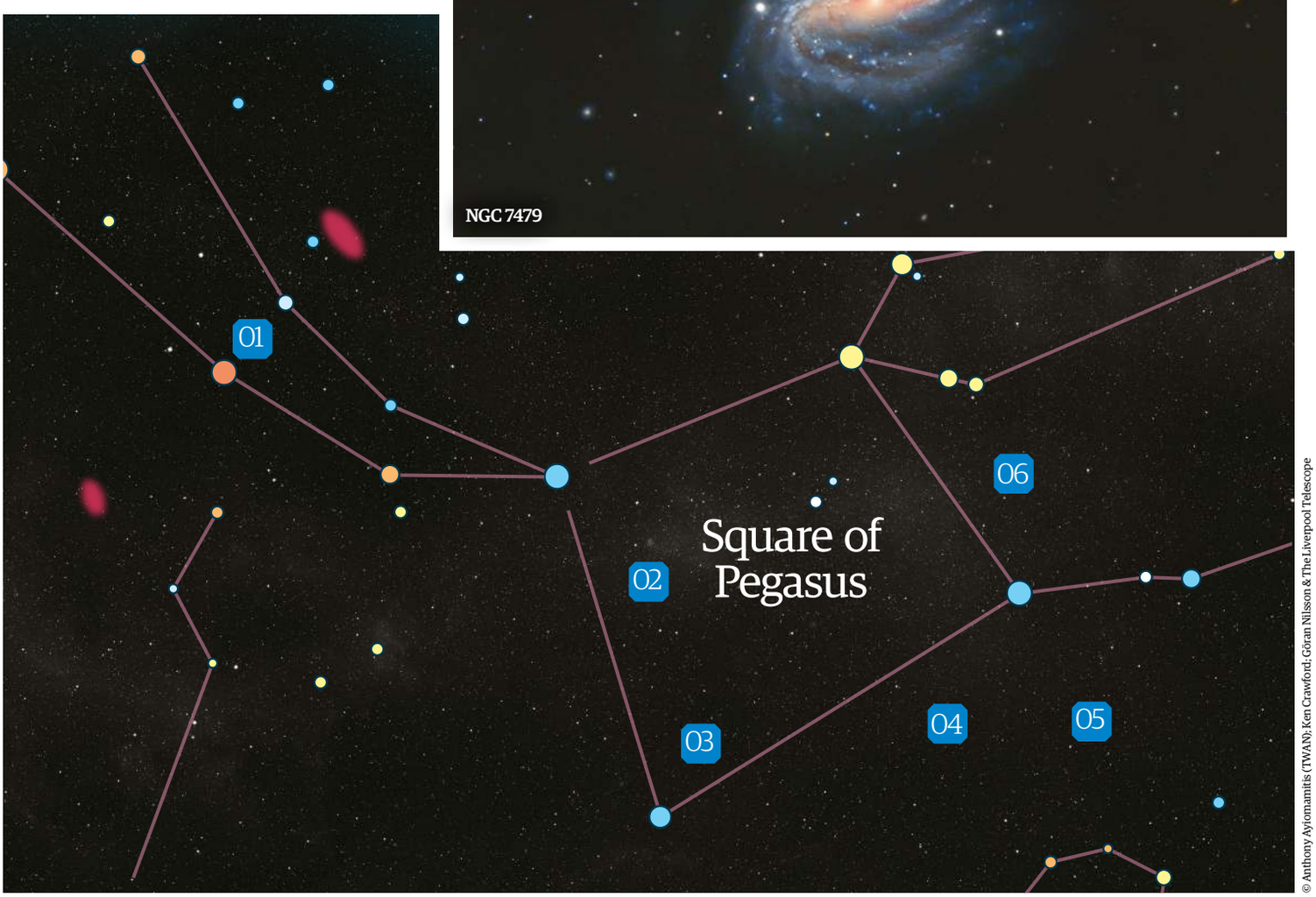
If you have a large telescope and a very dark sky you might be able to pick this magnitude 12.6 galaxy out. It is quite a large, extended object visually but has a low surface brightness.

5 NGC 7479

This distant barred spiral galaxy is a Seyfert galaxy undergoing violent starburst activity. It is visible in almost any telescope, but you'll need medium or large apertures under a dark sky to make out the graceful curves of its spiral arms.

6 51 Pegasi (Helvetios)

There's no 'challenge' to finding this star – at magnitude 5.4 it is visible to the naked eye – but it is worth tracking down for its celebrity status: in 1995 it was the first sun-like star found to have a planet (now named Dimidium) orbiting it.



How to...

Catch the International Space Station

This month there will be lots of opportunities to watch the Earth-orbiting outpost crossing the sky. If you've never seen it before, here's how – and no special equipment is needed

You'll need:

- ✔ Clear view of the sky
- ✔ Binoculars (optional)
- ✔ Website or app to provide visibility information

Many people are surprised to hear that it's possible to see the ISS in the sky. They think it's too high or too far away. But it's exactly because it's so high that we can see it: long after it's dark down here on the ground the ISS is still bathed in sunlight, and we can see the light reflecting off its solar panels and modules, making it look like a bright 'star' that drifts silently across the sky, travelling from west to east. Sometimes it reaches high in the sky, other times it barely clears the treetops. Sometimes it is almost as bright as Venus at its best, other times it's much fainter.

'ISS-spotting' is now very popular among amateur astronomers and stargazers, but if you've never seen it how do you know when to look for it, and how bright it will be?

There are many websites you can visit for this information. Just enter your location and they generate a table with details of the dates, times and brightnesses of any upcoming Space Station 'passes' visible from where you are.

More people now use apps on their tablets or phones – many of them free – to get this information. They are usually more accurate because they use GPS to calculate visibility information for your exact location, and most even generate a chart showing the ISS' track across the sky to help you plan your observations.

The ISS alternates between being visible in the evening and in the morning, so you might have to stay up late or get up really early to see it.

You don't need any equipment to see the ISS. Because it moves quite quickly it's almost impossible to follow it with a telescope. A pair of binoculars will make it look brighter and enhance its colour (it can look very orange sometimes) but you don't even have to have those; the ISS is clearly visible to the naked eye, often the brightest thing in the sky after the Moon and Venus.

> "The ISS alternates between being visible in the evening and in the morning, so you might have to stay up late"

Tips & tricks

Find a good observing site

You can see the ISS from your garden, but you'll have a much better view from somewhere with a more open view of the sky.

Get accurate information

Websites and apps give predictions of when the ISS will be visible from where you are, but don't look for times too far in advance. They can lose accuracy when calculating for future dates.

Start looking early

Don't head out just as the ISS is due to appear. Go out a few minutes before, just in case your predicted times have shifted slightly.

Take a closer look

The ISS is a bright naked-eye object, but it looks even more impressive through binoculars. They will make it look brighter and enhance its colour too.

Being prepared for a pass

There is plenty of software available to help you get ready to look for the ISS

Armed with your website- or app-generated information, head for somewhere with a big view of the sky. Aim to be there around ten minutes before the predicted start time of the pass. Face the west, and wait. Eventually you'll see a 'star' climbing up slowly from the horizon – that will be the ISS. Enjoy the view as the ISS arcs across the sky from your right to your left. Don't worry about taking photos or timing it, just watch it sailing peacefully through the constellations, possibly even passing the Moon.

Send your photos to
space@spaceanswers.com

1 Choose a suitable website

Use a website or an app on your tablet or phone to find out when the ISS will be visible from where you are.

2 Get a wide-open view

If you can, go watch the ISS from somewhere with a wide-open view of the sky, with a clear view from west to east.

3 Face the right direction

Face roughly west five to ten minutes before the pass is due to begin, waiting for a 'star' to appear climbing up from the horizon.

4 Try out binoculars

If you can, use 10x50 binoculars to enhance the brightness of the Space Station and any colour it is displaying, too.

5 Track the station

Follow the ISS moving across the sky for as long as you can, watching how it fades as it falls towards the east.

6 Give the crew a wave!

Wave at the Space Station as it flies overhead – one of the crew might be looking down from one of its windows taking your photo!

The Northern Hemisphere

Now well into autumn, the darkened skies bring some astronomical favourites

Cassiopeia (the Queen) and Cepheus (the King) lie in the dusty path of the Milky Way, offering not just a rich star field but impressive deep-sky objects. In particular, the Owl Cluster (NGC 457) is easy to pick out with decent binoculars, its 75 to 100 bright stars forming the shape of an owl with spread wings, while its bright double star Phi Cassiopeiae forms the celestial bird's eyes. Double star Alpha Cassiopeiae can easily be split, resolving a bright yellow primary and faint blue secondary and providing delightful view.

Use the constellations of Pegasus, Aquarius and Pisces and you'll be able to locate Cetus (the Sea Monster), which contains the remarkable variable star Mira, as well as a wide selection of galaxies.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

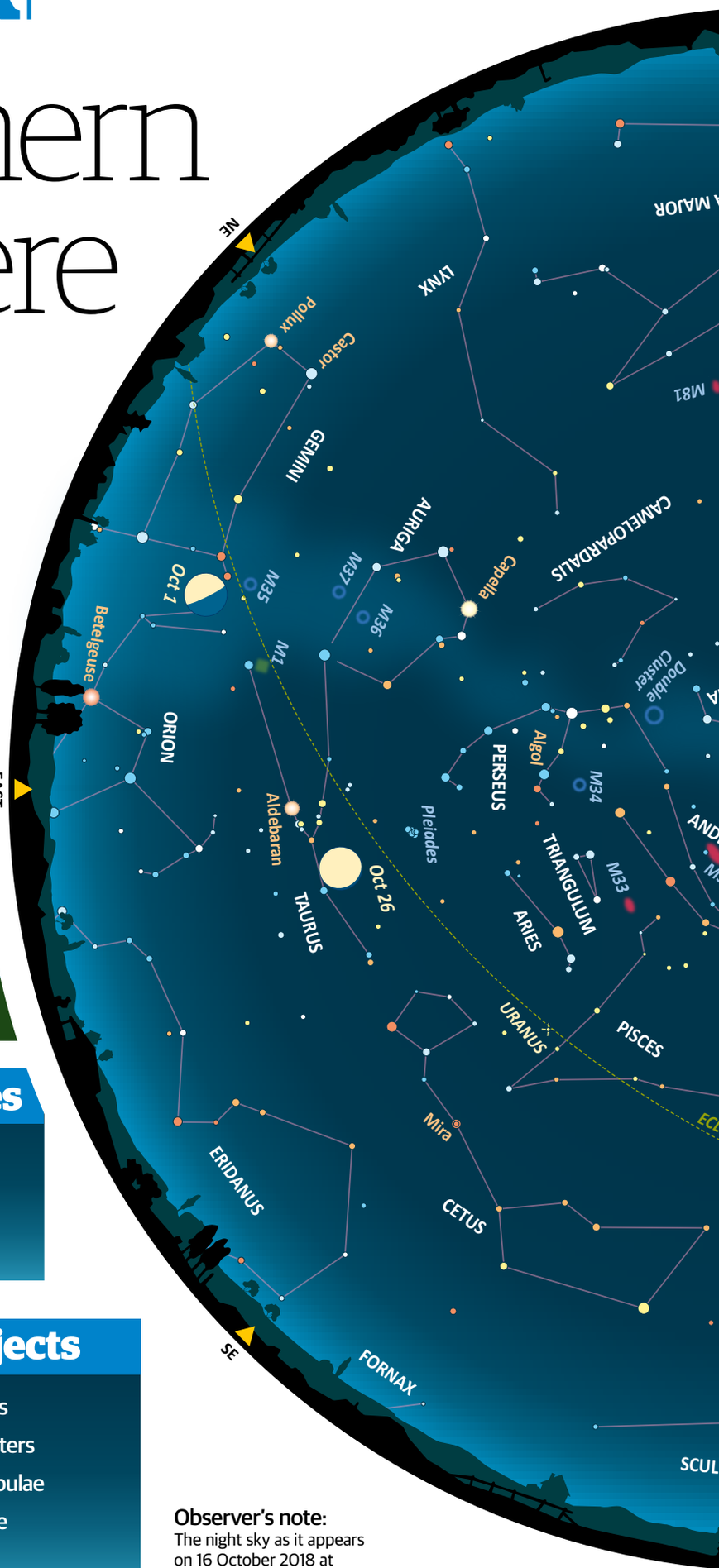
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

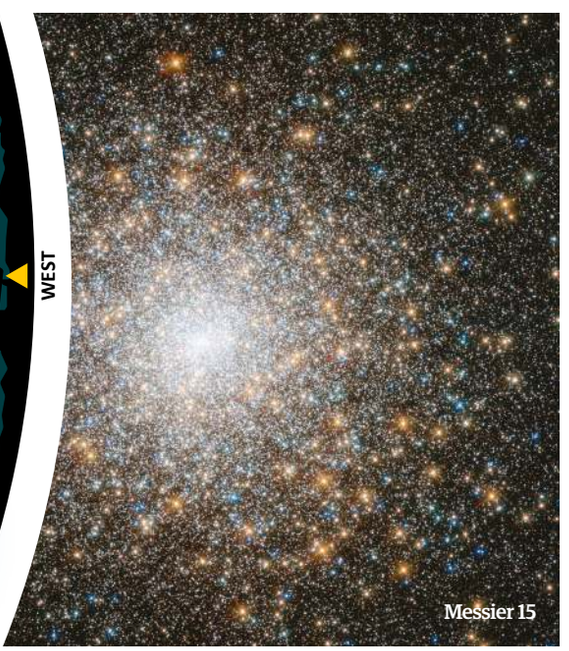
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 October 2018 at approximately 10pm (BST).


Triangulum Galaxy (M33)


Messier 15


The Double Cluster (Caldwell 14)

Astroshots *of the month*

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Cone Nebula (NGC 2264)

Warren Keller

West Virginia, USA
Telescope: 16-inch RCOS Ritchey-Chrétien owned by the University of North Carolina

"I began exploring the night sky at 15 years old with an eight-inch Newtonian during the 1960s. It wasn't until 1998 that I got my first taste of astroimaging with film, and in 2003 I switched to a CCD for capturing the treasures of the night sky. Artistic by nature, it's less about cosmology and more about the thrill of the hunt for the myriad beautiful shapes and colours throughout the universe. My astrophotography tutorial business has given thousands a quick start to taking their own great photos."

Henize 70

Pinwheel Galaxy (M101)

Patrick Gilliland

Worcestershire, UK & Calar Alto, Spain
Telescope: Officina Stellare RH 200 Astrograph, Borg 125 SC refractor, Takahashi 106 & Astro-Physics AP305

"I have always had an affinity with dark nights since I went on holiday as a child, sitting looking in amazement at all of the stars of the Milky Way. In recent years I decided to get more involved with astronomy, later embarking on a hobby in astrophotography. I have enrolled on a degree in astronomy and planetary science to better understand what I am imaging."

Jeff Johnson

Las Cruces, New Mexico
Telescope: Takahashi TOA-130F refractor

"I have a long love of astronomy and have observed the night sky for many years with binoculars and a telescope from the age of ten. I did my first 'real' astrophotography in 1996 when I used a 35mm SLR camera to take photos of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and just experimented with exposures. Later I bought a ten-inch Dobsonian for viewing. Within a week I was taking pictures through the eyepiece for fun, and within a few more weeks I knew I wanted to get serious with astroimaging."

Helix Nebula (NGC 7293)

Bode's Galaxy (M81)

Send your photos to... @spaceanswers space@spaceanswers.com

Celestron NexStar 4SE

A high-quality telescope for beginner and intermediate astronomers alike, this catadioptric is an instrument that promises years of usage

Telescope advice

Cost: £599 / $768
From: David Hinds Ltd
Type: Maksutov-Cassegrain
Aperture: 4.02"
Focal length: 52"

Unfortunately the telescope drains batteries very quickly, so we recommend purchasing a power cable from Celestron to operate the 'scope

It's not often that we come across a telescope that's an 'all rounder', but we were taken with the Celestron NexStar 4SE. It's quite difficult to outgrow this telescope given what it can offer and how easy it is to accessorise with extra eyepieces and other kit. The 25mm Plössl eyepiece supplied gives a magnification of 53x, but we'd advise purchasing a selection of eyepieces and filters, bearing in mind that the highest useful magnification is 241x, to get the very best out of this telescope

Setting this Maksutov-Cassegrain up took next to no time at all, and we were impressed with the quality of many of its components. The robust build of the NexStar 4SE promises to last for years of observing sessions, provided it is treated with care. We would recommend purchasing a dew shield for this telescope though, since catadioptric telescopes can succumb to moisture.

Weighing in at 9.53 kilograms (21 pounds) the telescope is a touch on the heavy side, but given the technology and components compacted into one instrument we weren't surprised. This is really just a minor inconvenience to those who would prefer a lighter scope.

Quite a large flaw in the telescope's design is that it requires eight AA batteries to operate the computerised fork mount. Sadly, the NexStar drains batteries quite quickly, making using it quite frustrating and giving it the potential to become quite expensive with more frequent use. We found that even with rechargeable batteries the telescope would act oddly with low charge, so we strongly recommend purchasing an AC power cord from Celestron. Unfortunately this is not included with the telescope.

The NexStar 4SE provided clear and bright views of night-sky targets with no defects such as colour fringing

Celestron promises a lot when it comes to the operational abilities of this instrument, so we were delighted to discover that the NexStar 4SE did exactly what the manufacturer said when we took it out to test on a clear September evening. Its star alignment using the SkyAlign technology was impressively simple, and it wasn't long before we began touring the late-summer sky.

Our first target was the Andromeda Galaxy, which is visible to the naked eye as a fuzzy patch. Instructing the NexStar to view this galaxy, the computerised mount ran smoothly and was very accurate at locating objects, with the galaxy sat very close to the centre of the field of view. When we brought the heart of the nebula into view we did notice a degree of vibration while focusing but, once finished, views could be taken in with no hindrance. Thanks to the excellent StarBright XLT optical coating, our observations of the galaxy and brighter satellite galaxies were very crisp, bright and clear, with no defects in the optics to speak of.

While the telescope slews to its target the mount does make a great deal of noise, particularly when we used the moderate to fast settings. If you find the noise off-putting and are happy to observe without a computerised mount then it's quite easy to switch over to a manual one, given that the tube possesses a Vixen-style dovetail. Remember though, you will need a Vixen adapter if you want to fit the tube to another Celestron mount.

Heading back inside to warm up with a cup of tea, we decided to give the NexStar's lunar, solar and sidereal tracking a test. On returning to the telescope 30 minutes later, we found that the star hadn't drifted out of the field of view, highlighting the telescope's excellent tracking ability. Many novice astronomers might find the idea of using a GoTo telescope daunting, but Celestron's comprehensive manuals and software will put any worries to bed.

With the nearly full Moon in the sky quite late into the evening, we took the opportunity to view our natural satellite's cratered surface. What we saw was impressive; NexStar revealed well-defined crater walls and lunar mare to a high standard – the craters Copernicus and Tycho were particularly impressive using the modest 4.02" aperture.

With gas giant Jupiter also at a good position in the sky and not too far from the Moon, the NexStar made short work of locating this planet and its four largest moons: Io, Europa, Ganymede and Callisto. Jupiter took pride of place in the field of view as a bright disc, with Ganymede and Europa appearing as sharp points of light flanking the giant's left, while Io and Callisto could be found relatively near to the planet's right limb. As discovered with Andromeda, views through the Schmidt-Cassegrain's optics were impressively clear and bright, with no colour fringing evident. Jupiter will only continue to make an excellent target by increasing the telescope's magnification, something we highly recommend doing, either by using a Barlow lens or filters, as well as additional eyepieces with a 1.25" fitting.

Despite a pricetag that many might find is way beyond their budget, we highly recommend the Celestron NexStar range, with the 4SE in particular being good value for money. With little-to-no maintenance required, provided you treat the telescope with care, this 'scope is one that will last a long time, providing impressive views of a wide selection of night sky targets. There's even room for basic astrophotography. A massive thumbs up from us!

The computerised fork mount makes finding your way around the night sky a breeze

Best for...

- Beginners and Intermediate
- Medium budget
- Planetary viewing
- Lunar viewing
- Deep-sky objects
- Basic astrophotography

The Maksutov-Cassegrain comes with a 1.25" 25mm eyepiece, as well as software and instruction manuals

WIN!

A SKY-WATCHER EXPLORER-130PS (AZ5) REFLECTOR TELESCOPE!

Courtesy of Optical Vision Ltd, this instrument is ready to be yours! All you need to do is answer our astronomy question

WORTH £300

This Sky-Watcher telescope, ideal for a beginner who needs an easy, grab-and-go instrument, is waiting to be won, thanks to Optical Vision Limited. There is a long list of fine celestial objects that can be revealed with this well-engineered Newtonian reflector, which features a 130-millimetre (5.1-inch), parabolic primary mirror and a superb AZ5 deluxe alt-azimuth mount.

This lightweight instrument still has the fine optic capabilities to reveal the craters on the Moon, Jupiter and its bands, Saturn and its rings and even an array of nebulae, galaxies and star clusters. With September now upon us summer is reaching its inevitable end and the nights are drawing in; what a way to celebrate these longer nights with a brand-new piece of kit!

To be in with a chance of winning, all you have to do is answer this question:

How many celestial objects make up the current Messier catalog?

A: 96 **B:** 103 **C:** 110

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Congratulations to Lee Keating, who is the winner of the Altair Astro GPCAM2 290C colour camera

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Software Universe Sandbox 2

Cost: £18.99 ($24.49) **From:** Steam Play

A space simulator that can be downloaded to your computer, *Universe Sandbox 2* is ideal for those who are keen to mix their love of gaming and the universe. Unlike many games on the market, however, *Universe Sandbox* doesn't have a mission, but you can have fun creating universes, playing with existing ones and the objects within them.

On the whole, the developers have impressively ensured that all the components (excluding the teapots) within this virtual cosmos – including planets, comets and stars – act as they should when obeying the laws of physics. If the user alters the systems in any way, chaos unfolds, revealing how the Solar System and even our galaxy could be affected if the balance of the universe is upset even slightly. In general, the premise of the game is simple – put various rocks in space, set various physical properties including velocity, mass and density, then watch them get to work. Whatever you decide to do – whether its making the Earth the same size as the Sun, throwing Mercury past the orbits of Uranus and Neptune or accidentally blowing up Jupiter and watching it form a second asteroid belt, *Universe Sandbox 2* is certainly worth having a play with, given its modest price tag.

App SkEye Pro

Cost: £4.73 (approx. $6.10) **From:** Google Play

An advanced planetarium for the astronomer, whether you're a beginner or have been touring the night sky for years, SkEye is the perfect companion for navigating the night sky. What's more this app – which can be downloaded to any Android device – is unique in the sense that you can strap it to a telescope or a pair of binoculars, allowing you to tour the night sky with the app and your instrument combined. A 'simpler' version of SkEye is also available as a free app for Android and Kindle Fire HD users.

SkEye's interface is smooth, as is its ability to track objects in the night sky. It is also quick at finding our favourite targets and, in comparison to other free apps, SkEye is very good at geo-aligning with accuracy and ease – something that beginners to astronomy will be extremely grateful for.

In an attempt to cater for a wide audience though, it has its drawbacks. Many of the Messier objects (galaxies, star clusters and nebulae) we found didn't have a great deal of information about them built into the app, something that may put off some users. If this doesn't bother you, SkEye certainly holds its own when navigating the night sky.

Book Rocket Men: The Daring Odyssey of Apollo 8

Cost: £18.99 ($24.49) **From:** Scribe Publications

Released 50 years after man first orbited the Moon, *Rocket Men* tells the inside story of Apollo 8, when the Apollo program was on shaky footing. This book, written by Robert Kurson, uncovers President Kennedy's end-of-the-decade deadline where his plans to put man on the Moon were in jeopardy and the Soviets were threatening to pull ahead in the Space Race. With time running out, NASA had four short months to prepare for one of the greatest missions in history.

Rocket Men focuses on the three heroic astronauts – Frank F. Borman, James A. "Jim" Lovell, Jr and William A. Anders – and their families, revealing the epic danger and bravery it took for humanity to leave the Earth for the very first time. Beautifully written with a vivid and gripping narrative, Kurson keeps the story simple yet explains the significance of the event in such a way that those with a passing interest in space exploration will be unable to put it down. Not dry in even the slightest, it's a non-fiction book like no other.

Accessories Celestron CG-4 Polar Axis Finder

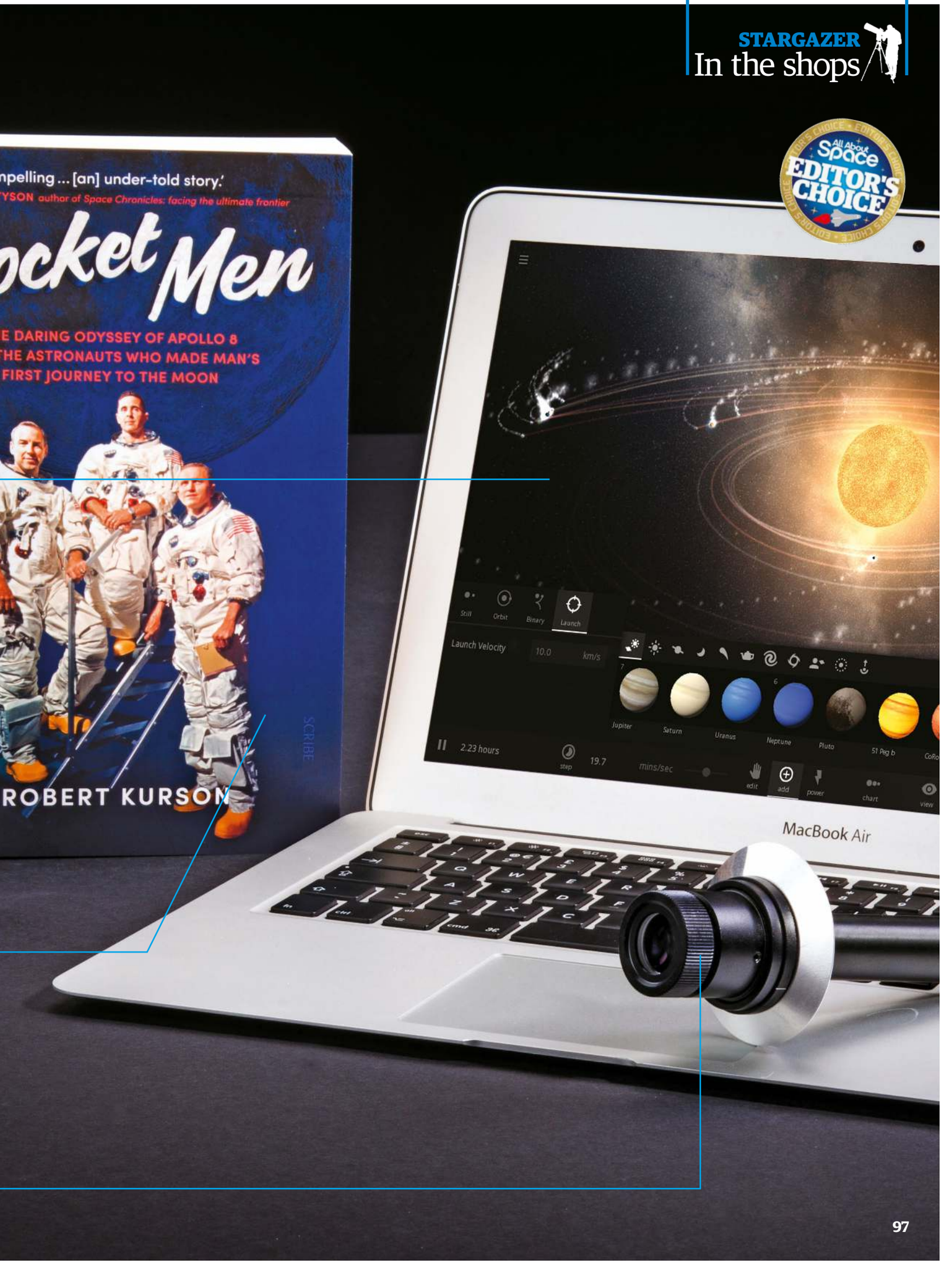
Cost: £39 (approx. $50.29) **From:** David Hinds Ltd

The aim of the Celestron CG-4 Polar Axis Finder is to aid you in setting up your equatorial mount rapidly and effectively – it features a focus control, protected screws and an 18mm aperture. Installing the accessory into the polar finder port of our telescope, located at the rear of the mount, was a breeze. Focusing the eyepiece was simple, and we were treated to clear and crisp views of the night sky.

What we found to be an incredibly useful feature was the star patterns that are etched into the reticle. We're in the Northern Hemisphere, so used the Big Dipper asterism as well as the familiar 'W' of Cassiopeia to guide us. The Big Dipper was more use to us during the summer and the spring, while Cassiopeia will serve observers best in the autumn and winter. If you're a Southern Hemisphere observer then the four stars of the constellation Octans is etched into the reticle.

Quality is excellent, as expected for a Celestron product, and placing North Star Polaris into the crosshairs after adjusting our azimuth and altitude controls was a breeze – now that we've used it, we really couldn't live without it.

"What we found to be an incredibly useful feature was the star patterns that are etched into the reticle"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Scott Carpenter

A true leader in NASA's campaign to reach space

When looking at the current state of NASA and acknowledging the constant presence astronauts have in space on board the International Space Station, it is important to look back on the trailblazers that paved the way. Scott Carpenter was a fundamental part of this movement, and this is heavily reflected in his accomplishments.

Born on 1 May 1925 in Boulder, Colorado, United States, as Malcolm Scott Carpenter, he gained a bachelor's degree in aeronautical engineering from the University of Colorado in 1949. However, the profession that truly led him down the path to becoming an astronaut was his position as a naval aviator, beginning in 1951.

On 7 October 1958, when NASA was only a few months old, Project Mercury was created. Its aims were clear: it was a head-to-head competition with the Soviet Union in a race to head to space. In order to sift out the weak, NASA constructed a harsh, but necessary astronaut selection criterion. Only seven candidates were deemed worthy of the position, mainly because of the fact they were all military test pilots. This was because NASA was adamant they needed men who could operate high-performance aircraft under stress. Carpenter was among these seven men, who became known as the 'Mercury Seven'.

Carpenter's time as part of the Mercury Seven crew was an incredible step forward in space exploration for the Americans, but they were still behind the Soviets. On 24 May 1962, Scott Carpenter boarded his Aurora 7 capsule on top of an Atlas rocket and became the second American to orbit the Earth, behind his colleague John Glenn, and the fourth American to make the journey into space.

Unfortunately, this journey didn't come without its problems. Soon after launch, the spacecraft's pitch horizon scanner, which is an essential device for navigation, had malfunctioned. Another problem was to follow when Carpenter had too eagerly used his manoeuvring jets to observe a ground flare experiment in Australia, which consequently depleted more fuel than anticipated.

This also caused heat build-up in the capsule, causing sweat to interfere with Carpenter's vision. Unknown to anyone at this point, the timing mechanism for the retro rockets on the heatshield was also not working properly, which could potentially have proven life-threatening upon re-entry.

With all these problems unfolding, Carpenter had no choice but to make minor re-entry adjustments to his falling capsule by manually steering the capsule and keeping the horizon in sight using his one and only window. Thankfully, Carpenter made it back to Earth, albeit 400 kilometres (250 miles) off the predetermined landing spot. After his recovery, Carpenter was awarded the NASA Distinguished Service Medal, the highest honour that NASA bestows.

After Project Mercury was closed in 1963, Carpenter became an aquanaut in the Sealab II program, and eventually went on to become executive assistant to the director of the Manned Spacecraft Center, which helped design the Apollo Lunar Landing Module.

Along with the NASA Distinguished Service Medal, Carpenter gained the Navy Legion of Merit, the Distinguished Flying Cross, the University of Colorado Recognition Medal and the Collier trophy.

Sadly, on 10 October 2013, Carpenter passed away in Denver, Colorado, United States, aged 88. The NASA administrator at the time, Charles Bolden, said Carpenter "was in the first vanguard of our space program - the pioneers who set the tone for our nation's pioneering efforts beyond Earth and accomplished so much for our nation," following his passing.

Carpenter only flew into space once, as part of the Aurora 7 mission

© NASA

"Carpenter became the second American to orbit the Earth, behind John Glenn"

All About Space

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- Highest Practical Power (Potential): x260
- Diameter of Primary Mirror: 130mm
- Telescope Focal Length: 650mm (f/5)
- Eyepieces Supplied (1.25"): 10mm & 25mm
- Parabolic Primary Mirror
- 0.5mm Ultra-Thin Secondary Mirror Supports
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- EQ2 Equatorial Mount
- Aluminium Tripod with Accessory Tray
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